Technical Report 636

Estimation of On-the-Job Training Costs for Satellite Communications Ground Station Equipment Repairers (MOS 26Y)

Robert S. Goldfarb and Stephen L. Mangum
George Washington University

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Manpower and Personnel Policy Research Group
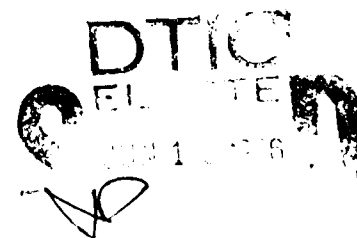**Manpower and Personnel Research Laboratory**

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U. S. Army

Research Institute for the Behavioral and Social Sciences

July 1984

REPORT DOCUMENTATION PAGE	READ INSTRUCTIONS BEFORE COMPLETING FORM	
1. REPORT NUMBER ARI Technical Report 636	2. GOVT ACCESSION NO. *AD-A168 40*	3. RECIPIENT'S CATALOG NUMBER
4. TITLE *(and Subtitle)* ESTIMATION OF ON-THE-JOB TRAINING COSTS FOR SATELLITE COMMUNICATIONS GROUND STATION EQUIPMENT REPAIRERS (MOS 26Y)	5. TYPE OF REPORT & PERIOD COVERED Final Report October 1982 – September 1983	
	6. PERFORMING ORG. REPORT NUMBER --	
7. AUTHOR(s) Robert S. Goldfarb Stephen L. Mangum	8. CONTRACT OR GRANT NUMBER(s) MDA 903-82-C-0383	
9. PERFORMING ORGANIZATION NAME AND ADDRESS The George Washington University 2000 L Street, NW, Suite 305 Washington, DC 20036	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS 2Q263731A792 211 3110	
11. CONTROLLING OFFICE NAME AND ADDRESS Human Resource Development Directorate Department of the Army, Deputy Chief of Staff for Personnel, Washington, DC 20310	12. REPORT DATE July 1984	
	13. NUMBER OF PAGES 109	
14. MONITORING AGENCY NAME & ADDRESS(If different from Controlling Office) U.S. Army Research Institute for the Behavioral and Social Sciences 5001 Eisenhower Avenue Alexandria, VA 22333-5600	15. SECURITY CLASS. (of this report) Unclassified	
	15a. DECLASSIFICATION/DOWNGRADING SCHEDULE --	

16. DISTRIBUTION STATEMENT *(of this Report)*

Approved for public release; distribution unlimited

17. DISTRIBUTION STATEMENT *(of the abstract entered in Block 20, If different from Report)*

--

18. SUPPLEMENTARY NOTES

Technical quality of this research monitored by Curtis L. Gilroy.

19. KEY WORDS *(Continue on reverse side if necessary and identify by block number)*

Economics	Military Occupational Specialty
Manpower	Human capital
Training	Military pay
On-the-job training	

20. ABSTRACT *(Continue on reverse side if necessary and identify by block number)*

   Traditionally, the U.S. Army has met its needs for skilled personnel through internal training systems. This internal system may be roughly divided into School training and On-the-Job Training (OJT). While fairly accurate cost figures are available for the former type of training, OJT costs are not currently being adequately measured by the Army.

   As the sophistication of defense systems increases, a growing demand for technical expertise also in demand in the civilian sector will   (Continued)

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20. (Continued)

require the most efficient personnel and training policies. In an effort
to increase the amount of OJT cost information available to policy makers
this study was undertaken to pilot an OJT cost methodology for the U.S.
Army. This research is built on previous efforts by the Navy and Air Force
to determine OJT costs.

A relatively sophisticated Military Occupational Specialty (MOS), Satel-
lite Communications Ground Station Equipment Repairer (MOS 26Y), was chosen
for study. Eighty percent of all supervisors in this field at two Army in-
stallations in the United States were interviewed to determine the initial
expertise level of soldiers graduating from resident training in this MOS,
the length of time devoted by soldiers and supervisors to On-the-Job Train-
ing in this MOS, and the approximate cost to the U.S. government of this
OJT period.

The results show that for this occupation OJT costs for soldiers alone
range from $4,764 to $19,334 per soldier. Supervisor time for OJT costs
is an average of $8,151. Therefore, total OJT for MOS 26Y ranges between
$12,915 and $27,485 per trainee.

This study demonstrates that OJT costs for technical occupations may
be obtained by the methodology used but are highly dependent on current
arrangements for trainee selection and training organization.
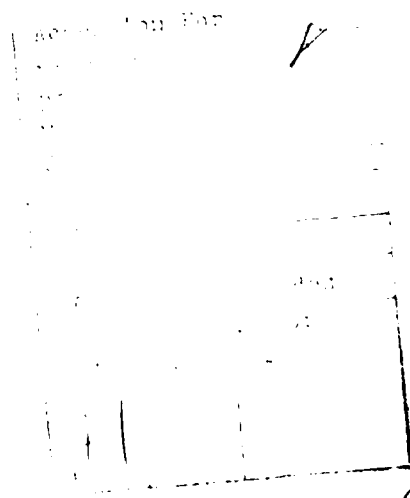
U. S. ARMY RESEARCH INSTITUTE
FOR THE BEHAVIORAL AND SOCIAL SCIENCES

A Field Operating Agency under the Jurisdiction of the Deputy Chief of Staff for Personnel

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Technical Director

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Commander

NOTICES

Estimation of On-the-Job Training Costs for Satellite Communications Ground Station Equipment Repairers (MOS 26Y)

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FOREWORD

The Manpower and Personnel Policy Research Group of the U.S. Army Research Institute (ARI) performs research in the economics and operations research aspects of manpower personnel and training issues of particular significance to the U.S. Army. The Army traditionally meets its demand for skilled personnel through a combination of resident school courses and On-the-Job Training (OJT). The costs of OJT, however, are not as well measured as the costs of resident training. As Army needs for skilled personnel increase, the efficiency with which those personnel are trained must also improve. Accurate measurement of OJT costs provides decision makers with greater information to allow the most efficient application of resources and personnel policies. This report was prepared as part of ARI's continual support for the Office of the Deputy Chief of Staff for Personnel.

The research presented in this report verifies a methodology by which U.S. Army OJT costs may be accurately estimated.

EDGAR M. JOHNSON
Technical Director

ESTIMATION OF ON-THE-JOB TRAINING COSTS FOR SATELLITE COMMUNICATIONS GROUND STATION EQUIPMENT REPAIRERS (MOS 26Y)

EXECUTIVE SUMMARY

Requirement:

The US Army Research Institute conducts research on manpower, personnel, and training issues of particular significance and interest to the US Army. As the Army's need for technically skilled soldiers increases the training of those soldiers takes on added significance. Traditionally military training has occurred in a combination of resident schools and on the job. To efficiently allocate resources between these two methods of training, the Army must have a more accurate estimate of the cost of On-the-Job Training than is currently available.

Procedure:

The authors selected a technically sophisticated Military Occupational Specialty (MOS), the Communications Ground Station Equipment Repairer (MOS 26Y) for investigation. Over eighty percent of the supervisors in this MOS at two US Army installations were interviewed to establish 1) the level of proficiency of a soldier upon graduation from resident instruction, 2) the time invested by trainee and supervisor in OJT and 3) the estimated opportunity cost of that time investment. Based on this information a path of output growth was calculated and compared to a progressive cost curve.

Findings:

OJT costs for MOS 26Y for trainees alone were found to range from $4,764 to $19,334 per trainee. The average per trainee supervisor cost for OJT in MOS 26Y was found to be $8,151. Therefore, the estimated cost to the US government of this training ranged from $12,915 to $27,485 per trainee.

DOCUMENT QUALITY ANALYSIS SHEET

DOCUMENT AD NUMBER	PAGE NUMBERS	SERVICE (ARMY, NAVY, AF, OR OTHER	MISSING PAGES	NON-REPRO-DUCIBILITY	POOR QUALITY 1-15%	CODE 23 MICRO-FICHE ONLY 16-50% ILLEGIBLE	CODE 22 REFER-ENCE ONLY 51% OR MORE ILLEGIBLE	OTHER ACTION
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Utilization of Findings:

This research demonstrates that the methodology employed to calculate OJT costs for MOS 26Y is generalizable to estimating OJT costs for all MOS's. These figures are useful to determine the relative proportion of resident training and OJT and the efficient allocation of training resources.

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Costs for Satellite Communications Ground Station
Equipment Repairers (MOS 26Y)

This final report presents results of a pilot study to estimate on-the-job training costs for Military Occupational Specialty 26Y, Satellite Communications Ground Station Equipment Repairer.

NATURE OF THE PROBLEM

The Army has traditionally met its needs for skilled personnel through an internal training system. The increasing sophistication of defense systems has prompted a growing demand for advanced technical skills also in demand in the civilian sector. In order to adequately evaluate whether substantial improvements are possible in the current internal training system, or to effectively consider the broader question of advantages and disadvantages of the current system versus alternative personnel systems, it is necessary at a very minimum to have dependable estimates of the per-trainee costs of current training efforts. Yet a major element of training costs -- those associated with on-the-job training -- are not currently being measured by the Army. The focus of this pilot study is on the measurement of these costs for one skilled technical occupation, satellite communications ground station equipment repairer (MOS 26Y).

Training in an occupation such as 26Y frequently takes place in two distinct phases. First, the trainee attends technical school (located at Fort Gordon for MOS 26Y) for a course of instruction of fixed duration. At the end of this course he is assigned to a field unit responsible for operational equipment. Upon arriving at the unit he is not a fully proficient technician; he needs additional "on-the-job training" (OJT) at the site in order to fully learn his skill. This OJT is often quite informal, in part

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involving the trainee watching and receiving "hands-on" experience in performing actual operation and repairs. While the Army has cost figures available for formal technical school training, there are no cost figures available for the OJT portion of the training. This pilot study investigates a method of providing estimates of these OJT costs for MOS 26Y. It is particularly important to provide such estimates, since Navy and Air Force studies of technical occupations suggest OJT costs can be a sizeable percent of total training costs.

HOW ARE OJT COSTS TO BE MEASURED?

Development of our costing methodology requires that we enumerate classes of costs associated with OJT, and then review how earlier Navy and Air Force studies have attempted to measure these costs.

Classes of Costs Associated with OJT

To estimate the Army's per-trainee costs associated with the OJT component of training, one would ideally want to determine the economic cost to the Army of all resources allocated to OJT activities. This would include, for example, (1) the per-trainee cost share of all administrative costs associated with assigning trainees to OJT slots, and any costs of developing and distributing special training materials; (2) the per-trainee share of cost of equipment "wear and tear" due to the training itself; (3) the net opportunity cost to the Army of the trainee's time spent in training; (4) the per-trainee cost of materials used up in the training process; and (5) the per-trainee cost of supervisor and other personnel time used up in this process of training. Because items (3) and (5) are likely to be especially important as a percent of total costs and because they require special techniques of estimation, our study focuses on estimating these classes of costs. An additional advantage of concentrating on (3) and (5) is that these categories of costs require information on supervisor and trainee time use, whereas the other three cost categories require outlay data likely to be found in accounting

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systems. Thus, since the source and location of information required for (3) and (5) is quite different from the other three cost categories, it makes sense to focus on (3) and (5) separately from the other three categories.

Review of Previous Literature on OJT Costing in the Military

In order to estimate OJT costs in a specific Army occupation, MOS 26Y, it is extremely helpful to review and evaluate previous attempts to cost on-the-job training activities in military settings. Since the late 1960s there have been a number of efforts made to estimate the costs of on-the-job training in military settings. These efforts, confined to the Air Force and the Navy, have used a variety of costing methodologies and have varied widely in complexity and scope. This review provides a general description of each study, emphasizing costing methodologies employed.

Since the purpose of this review is to aid in understanding the particular methodology and specific questionnaire we have chosen for our own research, the review stresses the advantages and disadvantages of particular measurement methods and survey questions, as highlighted by the way in which each previous study tried to improve on weaknesses in earlier studies. Detailed examination of the actual cost estimates in each study and consideration of why cost estimates in similar occupations varied widely across studies is reserved for Appendix I.

Weiher and Horowitz (1971)[1]

In the Navy, successful completion of a written exam in a rating (the Navy equivalent of an Army MOS) is required before an individual can reach the E-4 grade. Two alternative training paths lead to the point where trainees are deemed prepared to take the exam. One path involves time in formal classroom training (A-schools) followed by fleet assignment for on-the-job training in the particular rating. The alternative training path is direct duty assignment with skill acquisition solely through OJT.

Weiher and Horowitz analyzed Navy enlisted occupations with three

research questions in mind:

1. Which major skills can be learned on the job?
2. What are the learning curves (time paths of skill acquisition) for graduates of A-schools versus individuals acquiring skills through direct duty assignment (OJT) alone?
3. What are the relative costs of training an individual via formal training versus OJT to the point where he/she is qualified to take the 3rd class exam on the basis of job performance?[2]

A questionnaire was administered to approximately 1900 senior enlisted men responsible for OJT in Navy ratings. The ratings were consolidated into major specialties such as "Electronic Equipment Repairmen," "Communications Specialists," "Craftsmen," etc., for purposes of the analysis.[3]

The questionnaire asked supervisors an identical set of questions about A-school graduates and about non A-school trainees. The questions were phrased to obtain information on the typical or average trainee in the two groups. Major points addressed in the survey instrument were: the average OJT time necessary to get an individual qualified to take the 3rd class exam; the productivity profile of the two trainee groups; and the amount of time spent by senior personnel in OJT instruction. The instrument used by Weiher and Horowitz is unique in that it asked the respondent to draw a curve showing the time path to proficiency of a typical trainee in each of the two training paths relative to that of an individual fully qualified to take the 3rd class exam. Figure 1 shows the actual way the question was asked.[4] (The same question was then asked for A-school graduates.)

Training costs were computed from survey data, except for A-school costs which came from a supplementary source. Student OJT costs were defined as the number of months the typical individual spent in OJT preparing to qualify for the exam multiplied by the pay and allowance figure for an E-3. The dollar value of a typical trainee's monthly output was computed as the trainees' average proficiency for a given month (from the learning curve diagram), multiplied by an E-4's salary weighted by the typical individual's

In the graphs below, you are asked to indicate how the job skill level of trainees changes at different periods of their on-the-job training when compared to an individual who is qualified to take the 3rd class exam. The vertical axis extends to 100 percent, the point at which the trainee is professionally qualified to take the 3rd class examination. The horizontal axis is divided into one-month intervals.

On the first graph, mark your estimate of how the professional skill of a non-A-school man progresses during training compared to a man qualified to take the 3rd class exam, starting at the time that he strikes for and is working in your rating. Indicate his progress in one-month intervals with an X. The total time period you cover for this should agree with your answer to 1.A above. Make sure you indicate how professionally qualified the man is when he first starts striking and working in your rating by marking the vertical line for zero months.
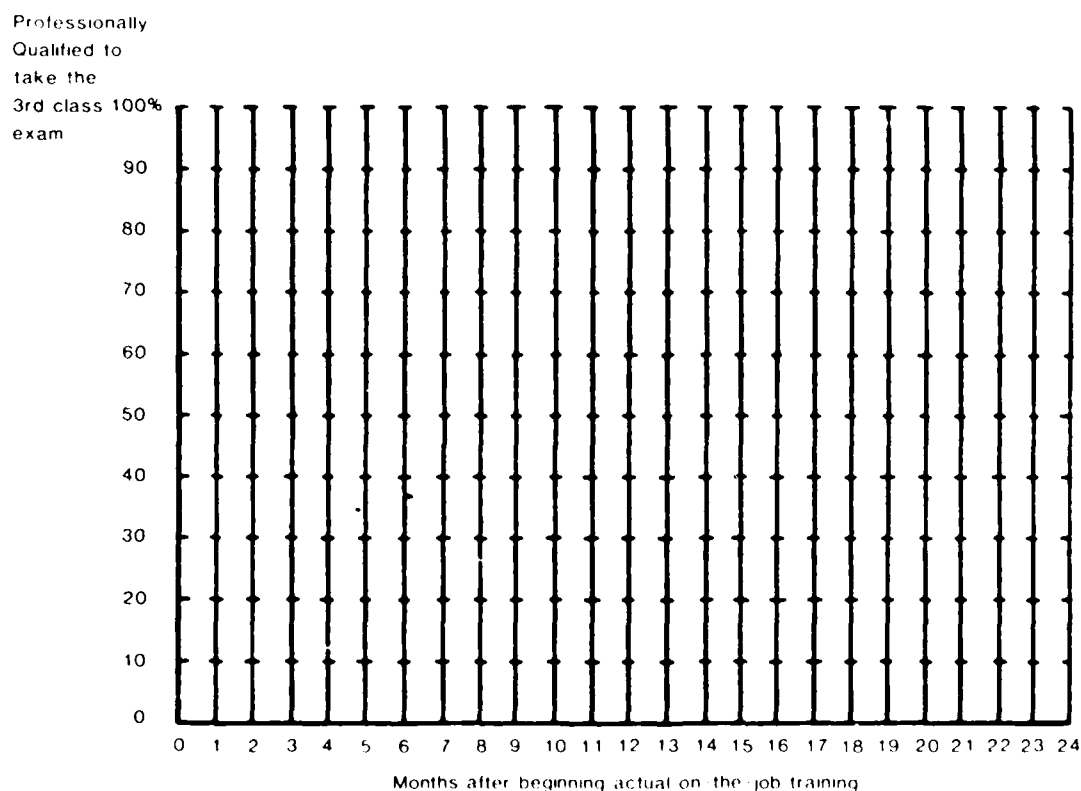
NON-A-SCHOOL TRAINEES

Figure 1. Weiher and Horowitz's relative proficiency question.

proficiency relative to an E-4. Summing this monthly output value over the length of OJT produced a dollar value of output during training. Supervisor costs under the two respective training regimes were arrived at by multiplying the proportion of time individuals of each supervisory grade spent in OJT instruction and supervision per trainee by the average number of months spent in OJT by the typical trainee. This product was then multiplied by the monthly pay and allowance package of each supervisory grade.

These items permitted calculation of cost estimates per test taker. Recognizing potential selection bias due to a tendency for nonrandom assignment to A-schools of individuals scoring high on entrance exams, the authors attempted to control for this by estimating the proportion of individuals in each training path who would have passed the exam if their training path had been randomly chosen. Cost per test passer estimates for both paths were then generated.

Among the important findings of this study are:
1. All ratings can be learned on the job.
2. A-school graduates require less OJT than do non A-school trainees and are more productive during OJT.
3. If supervisor costs are excluded, training costs are lower for non A-school trainees than for A-school graduates (except for the case of building craftsmen).
4. Conversely, if supervisor costs are included the finding reverses with costs being lower for A-school graduates (except for stewards and torpedomen).

These findings highlight the key importance of supervisor opportunity costs in the estimation of OJT costs. The authors concluded that if their estimates of total training costs are reliable "formal schooling appears more efficient for virtually all ratings." To justify shifting resources to OJT "it must be shown that supervision costs are considerably lower than the estimates made here. This is possible if either the respondents overestimated the time lost in OJT or if supervision time is worth less than the pay tables say it is."[5]

There is reason to believe that supervision costs in this study may have been overestimated. First, the questions concerning supervisor time spent in OJT instruction may have been misunderstood. The following

three-question sequence was repeated for each supervisory grade (E-4 to E-9).

How many E-9s are normally in the work area?

What percentage of their time do the E-9s spend instructing each
non-A-school on-the-job trainee?

What percentage of their time do the E-9s spend instructing each
A-school graduate on-the-job trainee?

The desired response was the amount of time the typical supervisor of
each grade spent with the typical on-the-job trainee during a time period.
It is easy to imagine the respondent's answers being based on time spent
with trainees in general (rather than individually) since this would be the
norm in the work setting. The potential for bias is compounded by conceivable
ambiguities in the phrase "normally in the work area."

Second, use of military pay to proxy the opportunity cost of supervisor
instruction time may be inappropriate in many occupations. Where supervisor
time is spent sitting around awaiting contingencies (that is, slack time
exists), the opportunity cost to OJT instruction would be low. This slack
time situation may be applicable to many military occupations, particularly
combat occupations. Weiher and Horowitz found that if OJT instruction
costs were assumed to be zero, the costs of training non-A-school trainees
were lower than those of training A-school graduates and the study's findings
reversed. Both of these considerations, particularly the first, point to
the possibility of overestimated supervision costs in this study, and a
resulting overestimate of OJT costs in general.[6]

In summary, Weiher and Horowitz cultivated the approach generally used
in OJT cost estimation efforts in the military. Asking respondents to draw
the trainee's learning curve is the questionnaire's most distinctive feature.
While the supervision costs emerging from this analysis may be suspect, the
work of Weiher and Horowitz, which itself built on earlier work[7], was the
point of departure for subsequent OJT cost estimation efforts.

Dunham (1972)[8]

Commenting in 1974 on the Dunham study, Rand's Robert M. Gay said:
"this is clearly the most detailed, precise study of OJT costs to date."[9]
Dunham's research focused on a single Air Force occupation (AFSC), the

Communications Center Operations Specialty. He provided a succinct rationale
for his attempt to estimate OJT costs in this Air Force occupation.

> "The cost of training the required personnel can be altered
> by varying the relative use of technical training school and
> OJT. The OJT-technical school mix may also affect the quality
> of trained airmen, the time necessary to meet a sudden increase
> in required operational capability, and the ability of units
> to maintain their operational effectiveness.... One necessary
> input is the cost of OJT...[this] can be compared to the cost
> of the corresponding technical training course, and an optimal
> mix of the two training approaches for the specialty under
> consideration can be determined."[10]

Air Force Category B specialties such as the Communications Center
Specialty are particularly appropriate for OJT-technical school comparison.
These specialities are staffed in two ways: (1) by individuals having
completed a formal resident technical training program (51% of the staffing);
and (2) by individuals who have been assigned directly out of basic training
and who acquire their specialty skills through an OJT program (49% of the
staffing).[11] Dunham's research involved estimating the cost of OJT needed
to achieve skill level 3 and comparing this figure to the cost of the
corresponding technical training school course.

Dunham identified the economic cost of OJT to be the production foregone
as a result of training and divided this into two broad areas: (1) materials
and equipment; and (2) student and instructor time. Dunham collected his
data by means of an elaborate questionnaire to training supervisors in the
specialty. The survey instrument's detail portrayed a thorough understanding
of the specific Air Force specialty and permitted estimation of some cost
elements not included in previous studies, such as:

1) time spent by trainees and supervisors in remedial training

2) time spent awaiting security clearances

3) time supervisors spent in record keeping

4) equipment and materials used in OJT

5) indirect OJT costs such as that of base and command OJT
   monitors and the cost per user of updating home study courses.

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Dunham's methodology for estimating trainee and supervisor time differed from that of previous studies. Rather than rely on the respondent's perception of full job proficiency, Dunham identified specific items or skills from the Air Force Specialty Training Standard (STS) to provide common terminology and a skill grouping with which the respondents were familiar. For each selected skill from STS the respondent was requested to record: the number of weeks to 3-level proficiency; trainee hours per week spent reading; trainee hours per week spent in OJT; instructor hours per week; and trainees per instructor.[12]

Dunham addressed two concerns raised with respect to the Weiher and Horowitz study. First, he asked for estimates of hours spent _per week_ in the various activities. Second, he asked supervisors to record the number of hours spent with all trainees during the week, and then asked for the typical number of trainees. He thereby escaped one of the problems thought to produce an overestimate of OJT supervision costs in the earlier study.

Of 214 mailed questionnaires, 113 were returned completed and 104 were deemed usable. Formulas for the cost elements were applied to the questionnaires, and means and standard deviations were computed for each question. The variance was large in the responses to several key questions. Dunham listed three factors potentially contributing to the high standard deviation in responses: 1) differences in the complexity of tasks at different communication centers; 2) differences in trainee quality; and 3) variation in supervisor estimates of the time required for OJT.

Summing OJT cost elements Dunham found trainee and supervisor time to represent 70% of estimated average total OJT costs. Eliminating Dunham's "time awaiting security clearance" cost element, trainee and supervisor time costs represented 90% of average measured OJT costs. This result is important, for as Robert Gay comments, "if this estimate is representative, it implies that the foregone productivity of trainees and supervisors is by far the dominant factor in OJT costs."[13] If the Dunham finding is generalizable, studies accurately measuring personnel opportunity costs will succeed in capturing the vast majority of relevant OJT costs.

Principal findings of Dunham's study include the following:

1. The average time to level 3 proficiency qualification in

the Communications Center Operations Specialty is eleven
weeks for OJT and twelve weeks for formal technical training.

2. "A new technical school graduate, a qualified 3 level, does
not have the productivity of an OJT trained 3 level until
more than four weeks after his arrival at the communications
center."[14]

3. In terms of the transfer of skills learned in technical school
to the first duty assignment, "one can expect that less than
50% of the material in the Career Development Course will be
applicable to the operations of a particular unit."[15]

4. Technical school training costs are 112 percent higher
than the median OJT estimate and "this difference is largely
attributable to equipment, training aids, and administration
costs which do not measurably exist for OJT."[16]

5. "Technical school and OJT methods teach the required course
material equally well for this career field."[17] Consequently,
"the relative costs would seem to indicate that the Air
Force should send as many personnel as possible to OJT in
this skill subject to manning constraints."[18]

Dunham's results seem diametrically opposed to those of Weiher and
Horowitz. His findings give OJT a significant cost effectiveness advantage
over formal technical training. Dunham uses these results to suggest that
for this occupation the Air Force should "send as many personnel as possible
to OJT." However, such a recommendation does not account for concerns such
as constraints in the personnel assignment system, and the sensitivity of
cost estimates to the size of the trainee flow.

Dunham identifies differences in unit operations and equipment as a
potential source of variation in OJT cost estimates. This realization is
an advance over previous studies which identified variation in trainee
quality as the only mentioned source of variance. Dunham warns:

"Continued use of this cost estimate in the future is valid
only to the extent that future knowledge and skill requirements

in this specialty correspond to the knowledge and skills
required when the cost estimate was made....Any radical change
in the specialty would require a reevaluation of the relevance
of this cost estimate."[19]

Dunham appears to have successfully handled many of the questionable
points of earlier studies. Robert Gay, however, identifies one weakness of
Dunham's approach that could bear on the strength of the results, rather
than the methodology.

"One limitation of Dunham's approach is that it is restricted
to the formal OJT program. Our interviews at the base level
strongly indicated that journeyman proficiency occurs after
completion of the formal OJT program, and if this is true,
this (Dunham's) procedure may not yield estimates of the full
cost of OJT."[20]

Gay (1974)[21]

Gay sought a technique permitting estimation of individual-specific
OJT costs. By matching trainees and supervisors and administering a
questionnaire to training supervisors, Gay was able to obtain proficiency
estimates on individual trainees. Information on time paths to proficiency
were then related to trainee characteristics to explain differences in
learning curves (i.e. differences in training histories).

Gay's survey instrument was the simplest of those reviewed, consistent
with his objective of developing a methodology sufficiently general
to be used in any occupation and across services. Essentially two questions
were posed to training supervisors.

1. "Approximately how many weeks would you estimate it takes
   between the time a typical trainee joins your unit until
   he starts being an asset to the unit? That is, how long
   is it until the value of his output is approximately
   equal to the value of the work lost by others who were
   supervising and instructing him?"

2. "Approximately how many months, from the time he joins
   the unit, do you estimate it takes the typical new trainee

to become a fully trained specialist capable of satisfactorily performing almost any job in the shop?"[22]

Figure 2 can be used to illustrate Gay's framework, and to show how these two questions provide empirical information for the framework. In Figure 2, the line which starts lower on the left vertical axis represents the value of the trainee's output during training minus the value of output foregone because experienced personnel are involved in training instead of production. We call this line the net productivity or net value-of-marginal-product (VMP) curve. The other line, which starts higher on the vertical axis, represents the value of the individual's output in his alternative military occupation -- the occupation he would have been in in the absence of training. Gay measures this output value by the individual's pay.

In terms of the diagram, Gay's first question indicates the point at which net productivity is zero, so that the net productivity (net VMP) curve intersects the horizontal axis at that point. The second question defines the length of the period of training. By assuming that (1) the net contribution to output (VMP) increases at a constant rate until full proficiency (a linear learning curve); (2) VMP remains constant from that point until the end of the first enlistment; and (3) that the value of a fully trained, fully proficient journeyman is equal to the wage rate at reenlistment following the first tour of service, the supervisor's information is sufficient to yield an estimate of OJT costs.[23]

The real innovation in Gay's study is found in the second half of the survey instrument. Questions identical to those above were posed to the supervisor, but for specific trainees rather than "the typical" trainee. Individual-specific OJT cost estimates were combined with background data on the individuals from personnel files. An equation was then estimated in which OJT training costs were regressed on variables such as race, marital status, prior education, years of civilian job experiences, scores on Air Force entrance aptitude exams, etc. This methodology permitted analysis of differences in estimated training costs attributable to differences in trainee characteristics.

Gay's study was conducted on the largest Air Force specialty, Aircraft Maintenance Specialists. A sample was drawn from a single base with approximately 700 members of this specialty. Thirty-six training supervisors
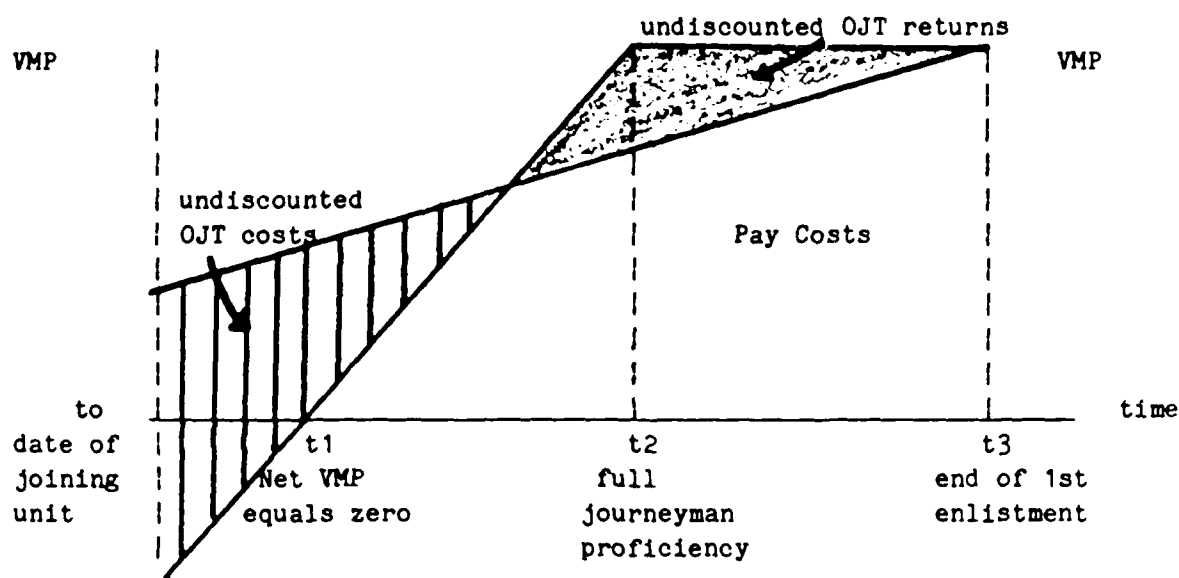
Figure 2. Robert Gay's model.

were asked to complete the questionnaire and provide information on 117 individual trainees. Twenty-four supervisors responded, providing the requisite data on 81 trainees.

Adding up relevant training costs of a typical trainee -- accession costs, technical school training costs, travel costs to assignment, OJT costs -- and comparing these to the value of the trainee's output during first enlistment, Gay documented a return of about 40 percent of the total estimated investment in training during the first enlistment. This indicates that the Air Force has a sizeable incentive to encourage trainees to reenlist. This incentive is the desire to recoup the net training investment (average of $6400 for this occupation) made in the individual.

By comparing the typical trainee approach and the individual trainee approach, Gay was the first to empirically investigate the effect of trainee attribute differences upon OJT costs.[24] He concluded that "the typical trainee approach gives seriously downward biased estimates of OJT costs."[25] He attributed this bias to the tendency of supervisors to give too little weight to high-cost trainees in the distribution when thinking about "the

typical trainee." To the extent his findings are representative of all trainees in this occupation, and this specialty is not atypical, Gay's findings may imply a sizeable underestimation of OJT costs by use of the typical trainee approach. Using data from a single base, Gay's study contributes little to the investigation of inter-base variation in OJT costs suggested by Dunham.

Gay made innovative use of his cost estimates. Regressing individual-specific OJT cost estimates on individual characteristics he estimated that an additional year of formal education prior to military enlistment would translate into a ten percent reduction in OJT costs. Interestingly, region of residence, years of civilian work experience, and race showed no conclusive relationship to OJT costs.[26] Further, Gay used his estimates of trainee productivity to investigate effects of changes in the experience mix of the force. Using estimates of the average productivity of the typical trainee at various stages of the training period he was able to equate a four-year enlistment of a trainee to 2.5 journeyman equivalent man years of labor. These figures are important in investigating the cost implications of changes in the applicant pool from which the military draws and changes in the experience mix of the services.

Samers et al. -- Phase I (July 1974)[27]

This report was the first of a two-phase research effort. Phase I consisted of developing alternative methodologies for the estimation of OJT costs for the Air Force "Administrative Specialty." Phase II involved the application of a preferred methodology to five additional Air Force Specialties (AFSCs).[28]

Dunham's earlier study was the point of departure for this effort--the stated goal being to improve upon Dunham's work.[29] Dunham's approach required supervisors to judge "average trainee" performance by recalling months (and years) of past experience. Samers termed this the "Aggregate Experience Approach." The study by Weiher and Horowitz and that of Robert Gay fall under the umbrella of the Aggregate Experience Approach. Samers proposed two alternatives to this approach, namely, the "Work Sampling Approach" and the "Self Recording Approach." The Work Sampling Approach involves asking supervisors about the training experiences of specific

trainees over the past week. The second approach, Self Recording, asks supervisors to record actual training experiences during a sample week.

Each approach has advantages and disadvantages. The Aggregate Experience Approach allows completion of the survey instrument in a single sitting and therefore may have administration cost advantages. It does, however, require extensive recall by supervisors, and has been shown to yield estimates with high variances. The Work Sampling approach may be subject to less response variance since the recall involved is more recent, but may require a larger initial sample to assure the presence of OJT trainees in the units sampled. The Self Recording Approach requires a larger initial sample than the other approaches to assure the presence of OJT trainees and to account for the increased likelihood of nonresponse bias (since this approach does not permit completion in a single sitting). On the benefit side, this approach involves less response variance since the requisite recall is limited to a single day (or at most a week).

Samers originally envisioned administration of three separate survey instruments, one conforming to each major approach. Concern with the unexpectedly small number of direct duty assigned OJT trainees in the selected specialty forced him to combine the approaches in a single questionnaire. After testing the questionnaire at bases in the San Antonio area, 295 surveys were mailed to a total of 30 bases, with the largest number at any one base being 15. Of the 207 surveys returned 199 were found usable, providing information on 270 trainees.

Part A of the survey instrument used the Aggregate Experience Approach and was very similar to the questionnaire in Dunham's original 1972 study. The two questionnaires are close to being identical throughout, with the exception that items selected from the Job Proficiency Guide (STS) were altered to reflect differences in the occupational specialties studied. Two questions not included in Dunham's study were added. The first involved a tabular rendition of Weiher and Horowitz's learning curve diagram. The supervisor was asked to list the average number of trainee productive and non-productive hours for various training weeks between the start of training and the award of the skill level.[30] The second addition required the supervisor to list the dates individual trainees entered skill level 3 training and the dates the AFSC was awarded.[31]

Part B of the questionnaire, the Work Sampling Approach, requested information on individual trainees and applied solely to the week preceding the administration of the questionnaire. The individual-specific nature of this section undoubtedly reflects the concerns expressed earlier by Robert Gay. In the Samers survey, the supervisor was asked to identify each trainee's current week of training, the trainee's present proficiency in comparison to a level 3, and his/her proficiency upon arrival in the unit. In addition, data were collected on the total hours of instruction and record keeping spent on selected tasks during the preceding week. Data on the relative proficiency of technical school trained and direct duty assigned OJT trainees were also collected.

The final section of the Samers questionnaire, the Self Recording Approach, has no precedent in earlier studies. Supervisors were requested to record daily, for the period of a week, the total hours all level 3 trainees spent reading and receiving instruction; and in activities contributing to office production. Finally, supervisors were to record the total hours of instruction provided by each grade of instructor. These completed training records were to be returned by mail at the end of the subsequent work week.

The combination of the three approaches in a single survey instrument permitted construction of multiple estimating equations for the respective cost elements. These alternative approaches were then compared in the selection of a preferred methodology. Samers results proved consistent with those of Dunham. Training individuals to level 3 in the Administrative Specialty by on-the-job training alone cost $1545 per trainee. For trainees completing technical training school prior to duty assignment total costs averaged $2281 per trainee. The authors termed this "a substantial difference." The average technical school graduate when assigned to a unit exhibited one-third the proficiency of a similar trainee trained entirely on the job, but only required an average of 4.5 weeks to close the gap. Samers work supports that of Lecznar (1972) and Dunham (1972), finding OJT trainees and technical school graduates to be of equal quality (as perceived by supervisors) once trained.

Total per trainee costs for the Air Force Administrative Specialty were distributed as follows: trainee time costs 37%; supervisor time costs

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38%; costs due to delayed entry 13%; record management costs 9%; remedial training costs 2.5%; and equipment and material costs 0.5%. An average of 18 weeks was needed to complete OJT in this specialty, the average week being composed of 10 hours of training and 25 hours of productive work. Each instructor averaged 9 hours of instruction per trainee per week.

Comparing methodologies, the authors concluded that estimates based on recollection of past experiences "yield high variance, biased estimates." The Self Recording Approach was praised for accurately measuring weekly training time in instances where large samples exist. Information on training duration was found to be "most properly derived from historical records."[32] Samers suggested combining approaches for use in the Phase II questionnaire. He concluded that the "Aggregate Experience" technique was good for estimating many of the small cost elements, but that major cost elements (trainee and supervisor time costs) were better estimated by journal record keeping and the use of existing data.[33]

Samers et al. -- Phase II (November 1974)[34]

This study is the application of Samers' preferred OJT costing methodology from Phase I to five additional Air Force Category B skill specialties: Pavement Maintenance Specialist, Fire Protection Specialist, Cook, Fuel Specialist, and Material Facilities Specialist. The survey instrument was designed to be specialty independent and drew heavily upon the self recording and work sampling methodologies for estimation of the major cost elements of trainee and supervisor time. Existing records were called upon for information on training duration, and the aggregate experience approach was used for estimation of small cost items where existing data were unavailable. It is interesting to note that the Phase II survey instrument eliminated derivation of individual trainee specific estimates that characterized Gay's (and part of Phase I's) work. Similarly, reference to a subset of specialty skills was missing in Phase II.

The most significant innovation of Phase II was the inclusion of "conditional cost models." Studies to this point had implicitly assumed that trainee and supervisor time were real costs; that is, if these individuals were not involved in training they would be engaged in some other productive activity (though in the case of trainees it might be at a lower skill level).

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Samers investigated the reality of this proposition by posing two additional questions. The first question asked: "If you stopped doing OJT training would you be able to reduce the number of NCOs in your work area without significantly reducing effectiveness?" A positive response was deemed consistent with the assumption that supervisor time is a real training cost. A negative response was taken to indicate that the NCO had other duties in the work area anyway, that training was a secondary or auxiliary activity, and that discontinuing OJT training in the unit would not lower costs.

The second additional question was: "If you stopped doing OJT training and had no replacements for the trainees could your section continue to perform its mission without significantly reducing effectiveness?" A "yes" answer was viewed as implying that trainees do not contribute to net productivity, and therefore, all trainee time costs are real training costs. A negative answer was interpreted as implying that trainees contribute to unit productivity. In this case productive time should not be counted a real element of training costs.

Surveys were mailed according to the following decision rule.

"Sample all available airmen in on-the-job training from the 1- to the 3-level at each CONUS Air Force base; however, no base shall receive more than 6 surveys in an AFSC."[35]

Some 527 surveys were sent to 76 bases. Only 228 usable surveys were returned due to changes in the trainee population by base as a result of transfers, upgradings, and discharges. This total included 30 in a pavement maintenance specialty; 25 in fire protection; 11 in the material facilities specialty; 90 in the cook AFSC; and 72 in the fuels specialty.[36]

Using records on training duration from base files, training hours per trainee from the survey instrument, and trainee pay and allowance package figures, Samers calculated an average trainee OJT time cost of $650 per trainee. Instructor time costs averaged $866 per trainee. Costs of remedial training, assignment delay, and record management added approximately $400 to average OJT costs. These figures were very similar to the Phase I estimate for the administrative specialty. For the five AFSCs: 3 level proficiency was attained after 19 weeks of training on average (18 weeks in the administrative specialty); the trainee spent an average of 13 hours per week in training (10 hours in the Phase I study); and instructors spent

about 12 hours per week per trainee in OJT instruction and record keeping (9 hours in Phase I).

The Phase II estimate that the average technical school graduate enters the unit one-third as proficient as an OJT trainee with equal service length compares closely to the Phase I estimate of 40 percent. Phase I found the proficiency gap between technical school graduates and OJT trainees closed in 4.5 weeks in contrast to Phase II's estimate of four weeks.[37]

Samers' conditional model yielded trainee and supervisor time cost estimates significantly different from those of the nonconditional model discussed above. Trainee costs in the conditional model averaged $1200 per trainee, while supervisor time costs averaged $100. Average total OJT costs were $300 less in the conditional case.

Thus,

"using conditional models implies a higher cost of the trainee's time, because the trainees may not contribute to productivity, and therefore all the time they are in training (for those who don't contribute) is a cost of training, just as it is for those in resident technical school. On the other hand in many of the training situations, the instructor's time is essentially free, since he must be there for other reasons, and in fact has free time to do training. On the balance when a more careful analysis of real costs is made conditional on the training situations as they actually exist, the conditional cost models have a lower average cost by about $300."[38]

The "low" supervisor cost estimate in the conditional model results from the fact that only 13 percent of the supervisors said their number could be reduced in the absence of OJT responsibilities without adversely affecting the unit's production. While this may be the case, this response is consistent with supervisor self interest. Supervisors may have anticipated the "appropriate" answer -- an answer projecting themselves as essential to unit effectiveness, irrespective of their OJT responsibilities. In contrast, the "high" conditional model estimate of trainee costs results from 36 percent of the units indicating that they could maintain their current production level if all trainees were removed. This figure may conceivably

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be biased upward in that supervisors may have the tendency to undervalue trainee contribution to the unit.

Samers found the costs of the technical training school (TTS) route to unit staffing to exceed the costs of the direct duty-OJT route in three of the five specialties analyzed: fire protection specialist, fuel specialist, and cook. OJT costs exceeded TTS costs in the cases of the pavement maintenance specialist and the material facilities specialist.[39] The authors underlined the fact that these cost differences spell cost savings only if the Air Force in fact acts to change its training mix in a manner consistent with the model's assumptions.[40] Since Phase II combined elements of earlier studies and contributed additional questions, it must be viewed as another iteration in the chronological improvement of survey techniques for generating OJT cost estimates, rather than a definitive statement of a best methodology.

Eisele et al (1979)[41]

This study is the most recent step in the progression of OJT costing methodologies in the Air Force. The study's goal was to generate cost estimates employing existing Air Force data systems,[42] both long established systems and those developed in response to the recommendations of earlier OJT studies. Consequently, the methodology in this study is best viewed in the context of a decade of Air Force OJT costing efforts.

The costing framework settled upon was driven more by practical than theoretical considerations, with the overriding criterion in cost factor selection being the "availability of quantification information through existing Air Force data structures." The cost elements estimated were 1) fixed overhead expenses -- the costs of regularly maintained OJT personnel at Air Force Headquarters, the major command levels, and the training command; 2) variable input costs -- the costs of supervision, unit administration, and the printing and distribution of career development course materials; and 3) capital expenditures -- the cost of developing and revising materials for career development courses. Other capital costs such as equipment usage, buildings, etc. were not included due to lack of practical methods for extracting such estimates from existing data sources. The opportunity cost of trainee time was another item seen as posing difficulties due to theoretical questions and a lack of existing data systems. Trainee time

was estimated however, as an alternative measure for inclusion at the user's discretion.

> "OJT trainees are expected to be somewhat productive, but less productive than they would be if already fully trained in their positions. The difference between the productivity of a fully trained airman and one who is in OJT, other things being equal, is a productivity loss associated with the OJT. Furthermore, the value of this productivity foregone by the airman in OJT can be seen as a cost of the OJT program. This interpretation of lost productivity has been the subject of enough controversy that trainee time factors have been included in the methodology as an option."[47]

Supervisor time costs were derived from the Air Force Occupational Survey Data Base. This data source solicits information on the number and types of tasks performed by supervisors of the various career fields and the relative amounts of time spent on specific tasks. This source was manipulated to yield trainee loads that were translated into annual costs per grade by application of the appropriate pay and allowance scales.

OJT direct personnel overhead costs such as management costs were arrived at by a telephone survey based on a massive organizational flow chart of personnel involved in OJT administration. The survey established the grade and OJT related time commitment of staff at headquarters, command and squadron levels. A similar procedure was utilized to determine support costs such as personnel involved in developing home study courses for trainees and instruction courses for OJT trainers.

Eisele applied his methodology and estimation techniques to six career fields: telecommunications operator; radio operator; integrated avionics; aircraft maintenance; helicopter mechanic; and missile systems maintenance. Since the Occupational Survey Data Base contains data on supervisory functions only, Eisele was unable to use this source in his "optional" estimate of trainee time. Instead, a survey was sent to the commanders of fourteen major commands. In the survey instrument the respondent was asked: "What is the percent of trainee productive time which is spent on duties specified in his specialty job description?" This estimate was used as a surrogate for OJT trainee productivity relative to a trained airman. "The remaining percentage of available trainee work time was used as an estimate of trainee time attributable to OJT, since this represents the productivity difference

between the OJT trainee and the trained counterpart."[44] Estimated trainee time costs were derived by applying personnel cost figures to OJT trainee month estimates.

Eisele found three factors to exercise the most influence on OJT costs in his selected specialties: trainee time cost, supervision time cost, and squadron OJT administration costs. The magnitudes of the cost factors varied from the $200 per trainee-month estimate of trainee time to the less than a dollar per trainee month estimate of Major Command OJT Overhead costs. Supervisor time costs averaged $50 per trainee month. Estimated monthly trainee OJT costs totaled $280 including trainee time ($80 excluding trainee time).

The authors concluded that "in summary, the power of (this) OJT costing methodology lies in its straightforward reliance on actual personnel counts and reliable existing data bases."[46] The definitiveness of this statement must be questioned. As in previous studies, trainee and supervisor time constituted a large proportion of total per trainee OJT cost estimates. Yet the estimate of trainee time used here was not derived from "reliable existing data bases" which supposedly was the major advantage of this methodology. Rather, the estimates for trainee time were based on a single question used in a survey of very limited sample size. Further, the trainee time estimates appear misstated.[47] This prompts questioning of the accuracy of the resulting average OJT cost estimates, particularly the estimates including trainee time. As the authors suggest, a more appropriate system for collecting data on trainee time, such as expansion of the Air Force Occupational Survey Data Base, would enhance the reliability of these cost estimates. Estimates of non-trainee time cost elements appear conceptually more sound and are perhaps the best available.

Summary

Beyond discussing specific cost estimates themselves, this review has uncovered a list of conceptual issues to be considered in any effort to estimate OJT costs:

- the theoretical validity of the estimation procedure
- the appropriateness of the survey versus interview versus data retrieval system approaches
- the real opportunity cost of supervisor and trainee time

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* the correctness of using salary and allowance packages
  as measures of opportunity cost
* the "individual" versus "typical" trainee approaches
* the tradeoff between occupation-general questionnaires and
  the peculiarities of specific occupations

Each of these issues must be given consideration in formulating a methodology
for costing on-the-job training activities. Beyond raising issues, this
review has documented the evolution of OJT costing efforts in military
settings. Data deficiencies suggest the iterations will continue.

The Cost Equations

Trainee Time Costs

Previous attempts to cost military on-the-job training activities have
displayed great variety in the size of the estimates. Assessing the sources
of these differences is made difficult by the number of occupations examined
and the variety of cost equations used. In Appendix I we examined the cost
equations of earlier research efforts in light of each study's theoretical
model. In some cases, the cost equations utilized were inconsistent with
the theoretical model and improperly estimated on-the-job training costs.
In other cases, cost equations conformed to the theoretical construct but
were found to involve such complexity and assume so much respondent insight
as to render the estimation procedure suspect.

Based on our understanding of the theoretical issues involved in OJT
cost estimation and the methodological difficulties of arriving at a reliable
estimate, we propose the following equation for estimating trainee time
costs in OJT:

$$
\begin{bmatrix}
\text{Time Periods of} & & \text{Opportunity Cost} \\
\text{OJT necessary for} & \bullet & \text{of a Trainee's OJT} \\
\text{trainee to reach} & & \text{time (cost per} \\
\text{full proficiency} & & \text{unit of time)}
\end{bmatrix} \quad \underline{\quad\quad}
$$

$$
\overset{\text{Time Units to}}{\underset{i=1}{\overset{\text{Proficiency}}{\sum}}}
\begin{bmatrix}
\text{Percent of Full} & & \text{The value of a} \\
\text{Proficiency} & & \text{fully proficient} \\
\text{reached during} & \bullet & \text{individual's} \\
\text{the ith time} & & \text{output per time} \\
\text{period of OJT} & & \text{period}
\end{bmatrix}
$$

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The term in the first parenthesis measures the cost of trainee time in terms of output foregone by having the individual involved in training rather than full production activities. The term in the second parenthesis recognizes that the trainee produces output during OJT and that the value of this output during training must be subtracted from gross trainee time costs to yield the net trainee time costs of OJT.

Supervisor Time Costs

Our desire to find theoretically sound and operationally simple cost equations lead us to the following equation in measuring supervisor time costs:

$$
\left[
\begin{array}{l}
\text{Time Periods of OJT} \\
\text{necessary for trainee} \\
\text{to reach full proficiency}
\end{array}
\right] \bullet
$$

$$
\sum_{k=1}^{\substack{\text{number of} \\ \text{supervisor} \\ \text{categories}}}
\left[
\frac{
\left(\begin{array}{l}\text{the value of} \\ \text{a grade k} \\ \text{supervisor's} \\ \text{output per} \\ \text{time period}\end{array}\right)
\left(\begin{array}{l}\text{percent of work} \\ \text{time supervisors} \\ \text{of grade k spend} \\ \text{in OJT instruction} \\ \text{per time period}\end{array}\right)
\left(\begin{array}{l}\text{number of supervisors} \\ \text{of grade k having} \\ \text{OJT responsibility} \\ \text{during time period}\end{array}\right)
}{\text{number of trainees}}
\right]
$$

DEVELOPMENT AND ADMINISTRATION OF A SURVEY
INSTRUMENT FOR ESTIMATING OJT COSTS

In developing a survey instrument for estimating OJT costs, our
major objectives were to formulate a questionnaire that would 1) give
operational form to the cost equations listed above; 2) examine different
questions which would be used to collect requisite information; and 3)
inasfar as possible, permit comparison on a single data set of cost
equations used in previous studies.   Previous attempts to cost
on-the-job training in military settings, have used three alternative
approaches: the Aggregate Experience, the Work Sampling, and the Self
Recording approaches.

Upon consideration of the major approaches used in OJT cost estimation,
the choice was made to employ the Aggregate Experience approach. A
number of factors led to this decision. First, our exposure to the Army
training establishment has not uncovered a straightforward data retrieval
system to provide the information being sought. The use of Job Books
and other training reports at the unit level appear too incomplete to
permit cost estimation from existing data. Second, to our knowledge
there is no cost effective method available to us for matching supervisors
to individual trainees to provide individual specific OJT cost estimates.
Third, the Aggregate Experience approach has an established track record.
Though not without deficiencies it will provide a starting point for OJT
costing in the U.S. Army. Fourth, this approach offers the advantage of
comparability. The cost estimates derived here can be compared to previous
(nonArmy) costing efforts. Finally, concern over the number of bases to
which access would eventually be granted and the sample size available
at those bases suggested use of a methodology minimizing sample size
concerns. For all of these reasons the Aggregate Experience approach
was selected.

A variety of specific approaches fall under the umbrella of the
Aggregate Experience approach. For purposes of this pilot study -- the
estimation of OJT costs for Satellite Communications Ground Station
Equipment Repairers (MOS 26Y) -- a "typical trainee" approach was decided

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upon. Moreover, in light of the variety of methods falling under the umbrella of the Aggregate Experience approach and no a priori way to assess their relative values, a questionnaire prototype was constructed representing a composite of previous methodologies and new questions based specifically on our pre-interview knowledge of MOS 26Y. Questions used in previous studies were altered to reflect the idiosyncracies of the Satellite Communications Equipment Repairer occupation and the institutional realities of the Army instead of the service branches in which the questions had originally been utilized.

Having made an initial attempt to construct a survey instrument for MOS 26Y, we pretested the questionnaire on a Washington-based individual with many years of supervisory experience in MOS 26Y. The pretest and associated discussions raised issues not addressed in our initial questionnaire. The interviewee's description of the MOS and the Army training process suggested additional areas for data collection and questioning. Since we had not been to an Army base at this juncture, these discussions provided material for sharpening our views about MOS 26Y and the questionnaire.

Armed with this new information, the survey instrument was reworked. Questions were added and others discarded to reflect our new perceptions. For example, concern over inter-base variation in costs due to equipment differences prompted a question to identify such differences by unit as they might correlate to cost estimates. The suggestion that some MOS 26Y training opportunities are dependent upon downtime (breakdown rates) gave rise to a set of questions providing estimates on a subset of the MOS tasks. Similarly, questions were added to investigate the existence of slack time in this MOS and its impact upon real versus observed opportunity costs.

Following ARI internal review of the revised questionnaire, a second session was scheduled with our Washington contact. In this session, he was asked to complete the instrument based on his experience in MOS 26Y and to verbalize his thoughts while doing so. Some terms that seemed conceptually clear to us gave him problems or had different connotations than we expected. By listening to his interpretation of a question, and then vocalizing our intent, we were able to rephrase our questions in

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language more appropriate to our respondent group.

After updating the questions to reflect the second round of input, the survey instrument was submitted to the Army Research Institute for U.S. Army clearance. This led to addition of several questions reflecting experience of other ARI researchers in studying time use in occupations different from MOS 26Y.

The Questionnaire

The final version of the questionnaire developed for estimation of OJT costs in MOS 26Y can be found in Appendix II. The survey instrument focuses on estimation of trainee costs (the opportunity cost of trainee time) and supervisor costs (the opportunity cost of time spent in OJT instruction and OJT related records management).

The first three questions of the survey seek information on the organizational makeup of the typical work unit--particularly the mix of trainees and supervisory personnel by level of seniority. In addition, these questions look at the routes to unit assignment by asking from what sources trainees came to the unit.

Question 4 is the first to deal directly with estimation of the time path to proficiency (the learning curve). It provides the definition of full proficiency to be used throughout the questionnaire ("someone of Skill Level 2 you can send to repair any malfunction: who can gather all necessary materials, repair the malfunction, and document it without direct supervision") and asks the supervisor to record the average proficiency of trainees arriving in the unit in comparison to the proficiency of the "fully proficient" ideal.

Question 5A recognizes that some individuals remain in a training phase indefinitely, never mastering the requisite skills. The question enumerates this percentage but, more importantly, is meant to help the respondent eliminate these individuals from consideration in answering subsequent questions in the survey. Question 5Bi provides an estimate of months to full proficiency for those who do eventually reach proficiency. Question 5Bii asks for an estimate of time to proficiency for the top 20% of trainees. This will provide a very limited look at the variability

of OJT costs to trainee quality.

Question 6 seeks a comparison between the fully proficient individual and the average "nontrainee" in the unit. This information can be used in an alternative formulation of OJT costs where these costs are computed on the basis of some critical skill level rather than full proficiency.

Questions 7 through 9 superficially investigate the level of human resource utilization in the unit. Question 7 explores whether trainees make a net contribution to unit production by asking if elimination of trainees, while maintaining the present number of supervisory personnel, would decrease unit production. A yes response implies that trainees do contribute to production and that trainee costs are divisible into training and production components. A negative answer is taken to imply that such costs are attributable to training alone since no positive net output is produced by trainees during training. Question 9 seeks similar information but is phrased in terms of whether the number of supervisory personnel could be reduced in the unit without affecting output if all OJT-related activities were terminated. The question seeks perceptions on the existence of supervisor slack time. A negative response to the question is interpreted as meaning the supervisor is needed on the worksite irrespective of training obligations. Consequently no opportunity cost is involved in the supervisory input to OJT. Question 8 looks at supervisory time utilization in a different perspective, asking how many additional trainees the unit could absorb (the number of supervisors held constant) without adversely affecting unit operations.

Question 10 provides the foundation for a second estimate of trainee OJT costs. Whereas the first method provided information on two points of the learning curve, this question tries to more explicitly determine the time path to proficiency. Estimates of relative proficiency are collected for 1, 3, 6, 12, and 18 months of training.

Question 11 was prompted by the Dunham methodology discussed earlier. The respondent is asked to estimate the percentage of time a trainee spends in OJT-related activities at different points in the training cycle. Assuming remaining time is devoted to full production activities permits an OJT trainee cost measure in the spirit of Dunham. Our estimation

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procedure differs from Dunham's in that it is not based on a skill subset and permits analysis of how the intensity of OJT activity changes over the training period.

Question 12 is the basis for estimating supervisor involvement in OJT. The first subquestion (12a) seeks information on the number of senior personnel having OJT-related contact with trainees during a typical week. E8s and E9s are not included in this list because they are not authorized on the worksite. Part b of the question collects data on the average weekly number of hours an individual of each supervisory grade spends in OJT activities. When combined with the number of trainees, this information will yield supervisor cost estimates per trainee. Part c is needed for translating monthly salary and allowance figures into hourly amounts to be attributed to the training function (when salaries are used as the relevant opportunity cost measure).[49]

Questions 13 to 16 provide a third major estimate of trainee OJT costs based on a representative sample of tasks taken from the MOS 26Y Soldier's Manual. The selected tasks include complex skills of repair and more ordinary tasks of daily maintenance. The questions do not ask for skill specific estimates of time to proficiency as common in past surveys. The six tasks are treated together, proficiency defined in terms of the group of tasks.

In Question 17 the respondent is asked to list types of terminals found on his/her worksite. This question was prompted by belief that terminals of differing sophistication across installations could influence OJT time on site and consequently OJT costs. By gathering data on equipment differences, this question will contribute to analysis of inter-installation variations in OJT cost estimates.

Question 18 is a lead into the more interesting question that follows it, but does provide a minor check on information provided in Question 11. Question 19 recognizes alternative demands on the trainee's time and asks the respondent to indicate the two primary factors preventing more time from being devoted to production activities. Training would seem a major candidate but most certainly not the only alternative use of time.

From Questionnaire to Cost Equations

The questionnaire was structured to yield information necessary to estimate the cost equations mentioned earlier. Of major importance in each cost equation is specification of a proxy for the opportunity cost elements--such as the value of a trainee's time in his/her next best alternative (nontrainee) employment. For purposes of this report we have followed previous studies and valued individual time in terms of military pay and allowances. This would seem appropriate for many internal Army uses though it does raise theoretical concerns making it less appropriate for other uses.[50] For the trainee time cost equation:

$$
\left[
\begin{array}{l l}
\text{Time Periods of} & \text{Opportunity Cost} \\
\text{OJT necessary for} \quad * & \text{of a Trainee's OJT} \\
\text{trainee to reach} & \text{time (cost per} \\
\text{full proficiency} & \text{unit of time)}
\end{array}
\right] =
$$

$$
\begin{array}{c}
\text{Time units to} \\
\text{Proficiency} \\
\sum \\
i=1
\end{array}
\left[
\begin{array}{l l}
\text{Percent of Full} & \text{The value of a} \\
\text{Proficiency} & \text{fully proficient} \\
\text{reached during} \quad * & \text{individual's} \\
\text{the ith time} & \text{output per time} \\
\text{period of OJT} & \text{period}
\end{array}
\right]
$$

We value the opportunity cost of trainee time in terms of the salary and benefit package of an E-3. The E-3 level was chosen because most trainees beginning OJT in this occupation are E-3's. In valuing output during training we value production at the pay and benefit level of an E-5.[51]

Respondent answers to Question 4 were used to identify trainee proficiency upon entry to the unit; that is, at the completion of AIT and the beginning of on-the-job training in the unit. Similarly, Question 5B1 was used to determine the months of OJT required for attainment of full proficiency. Two alternative methods were employed to estimate the trainee's level of proficiency at each month during the OJT process. In the first, a linear relationship was assumed between entry proficiency and full proficiency, i.e., proficiency was assumed to increase by a constant amount from unit

entry to full proficiency such that 100 percent proficiency was reached in accordance with the respondent's answer to Question 5Bi. In the second estimation method responses to Question 11 were used to identify additional points on the "typical trainee's" learning curve. The curve was then estimated in a piece-wise linear fashion.[52]

For the supervisor cost equation:

$$
\left[\begin{array}{l} \text{Time Period of OJT} \\ \text{necessary for trainee} \\ \text{to reach full proficiency} \end{array} \right] \bullet
$$

$$
\left\{ \begin{array}{c} \text{number of} \\ \text{supervisor} \\ \text{categories} \\ \sum \\ k=1 \end{array} \frac{\left(\begin{array}{l} \text{the value of} \\ \text{a grade k} \\ \text{supervisor's} \\ \text{output per} \\ \text{time period} \end{array} \right) \left(\begin{array}{l} \text{percent of work} \\ \text{time supervisors} \\ \text{of grade k spend} \\ \text{in OJT instruction} \\ \text{per time period} \end{array} \right) \left(\begin{array}{l} \text{number of supervisors} \\ \text{of grade k having} \\ \text{OJT responsibility} \\ \text{during time period} \end{array} \right)}{\textit{number of trainees}} \right\}
$$

Supervisor time was valued in terms of the salary and benefit packages of the particular supervisor grades involved.[53] Average supervisor time in OJT was determined by Question 12b. Question 12a indicated the number of individuals serving OJT supervisory roles in the unit. As in estimation of trainee time costs, Question 5Bi supplied information on the months of OJT required for attainment of full proficiency. Questions 1 and 2 were used to determine the number of trainees over which supervisory involvement was to be spread.

Administration of the OJT Questionnaire

For this pilot study the decision was made to administer the questionnaire in person rather than by mail. First, we were very much interested in any extra information that discussion with respondents might yield. This additional information would be useful in improving the questionnaire in preparation for future OJT costing efforts; in gaining understanding and appreciation of institutional realities impacting upon Army OJT; and in highlighting broader issues not specifically addressed by this narrow research effort. Second, the relatively small numbers of

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26Y's in total and the even smaller numbers at the two installations
where access was finally granted made us quite protective of each
observation. Mail-in surveys in the past have experienced return rates
on usable questionnaires of 50 percent at best. Not having many
observations to sacrifice strengthened the decision to personally administer
the questionnaire.[54]

The survey instrument was administered at two locations, at Fort
Detrick, Maryland and at Camp Roberts, California. At each site all
personnel involved seemed interested in sharing their experiences and
knowledge. Situations were very different at the two bases--differences
important in exploring inter-base variation in OJT costs. The installation
at Fort Detrick operates three distinctive types of equipment: an Earth
Terminal, a DSCSOC, and an AN/MSQ 114. The Earth Terminal physically
transmits to and receives messages from the satellite. The DSCSOC controls
the allocation of the satellite "channels" among users. The AN/MSQ 114
provides satellite communications facilities for communications among
Army tactical ground forces. In contrast, Camp Roberts currently operates
only an Earth Terminal, though an AN/MSQ 114 is expected soon,[55] and a
DSCSOC installation is currently under construction. The installation
at Camp Roberts has a significant contingent of civilian personnel (mainly
former military who stayed on in GS slots) who are actively involved in
day to day maintenance and repair activities on the site. While there
are some civilians on site at Fort Detrick, their influence did not seem
as evident as at Camp Roberts (more on this later). Consequently while
the basic services provided by the two installations are similar,
differences in equipment and personnel manning appeared to be factors
potentially affecting OJT costs differentially at the two bases.

The questionnaire was completed by 19 individuals at Fort Detrick
and 13 individuals at Camp Roberts. Thus, the cost estimates reported
in this pilot study are based on information provided by 32 individuals.
While these numbers are small they represent a sizeable proportion of
all 26Y supervisory personnel at the two installations.

ANALYSIS OF RESULTS

The Cost Estimates

For each valid questionnaire, trainee and supervisor time costs
were calculated according to the costing equations described above.
Table I shows the means and standard deviations of these cost estimates
by installation and type of equipment. The table provides estimates of
the two cost elements under different costing methodologies. The average
total cost of OJT for MOS 26Y across the two installations was $12,915
when trainee time costs were estimated using a linear approximation of
the proficiency (learning) curve. Trainee time costs ($4764) represented
37 percent of this total while average supervisory costs amounted to
$8151. Average total OJT costs were higher when trainee time costs were
estimated in a piece-wise linear fashion, $13,661.

The range of total OJT costs estimates produced by individual
questionnaires is illustrated in the histogram of Figure 3. Comparison
of the mean and median indicates the distribution of the estimates is
slightly skewed to the right. The sizeable standard deviation of the
cost estimates undoubtedly reflects many of the influences mentioned in
earlier studies, such as variance in the quality of individual trainees.
Table I highlights additional factors contributing to the variance in
cost estimates: equipment differences, differences in perceptions between
military and civilian supervisors, and differences between installations.

The cost estimates from Fort Detrick illustrate the influence of
equipment differences. The mean estimate of trainee time costs by
supervisors assigned to the Earth Terminal is noticeably less than the
trainee cost estimate for the AN/MSQ 114 or the DSCSOC. The DSCSOC is the
newest equipment acquisition and it should not be surprising to find
that it also has the highest estimated average trainee time cost. (Figure
4 shows the learning curves associated with these cost estimates by type
of equipment.) Interestingly, the average estimate of supervisor time
costs is largest for the AN/MSQ 114 and lowest for the DSCSOC. The table
clearly indicates equipment differences to be a factor contributing to
variation in OJT cost estimates at Fort Detrick.

Table 1

Mean OJT Cost Estimates

|	Fort Detrick, Md.				Camp Roberts, CA			Both Installations
	Total	Earth Terminal	114	DSCSOC	Total	Military	Civilians	
Trainee Time Costs								
Linear Method	$ 4,433	4,088	4,278	5,957	5,246	6,131	3,256	4,764
Standard Deviation	2,595	2,176	3,710	2,284	2,779	2,825	1,413	2,658
Piece Wise Linear Method	$ 5,226	3,899	6,966	9,040	5,911	6,533	4,045	5,509
Standard Deviation	3,894	3,180	4,803	3,531	4,734	5,090	3,553	4,192
Conditional Model	18,723	16,697	20,494	23,200	20,225	22,771	14,500	19,334
Standard Deviation	6,274	7,551	3,769	-0-	7,878	8,075	3,349	6,979
Supervisor Time Costs								
Mean	7,708	7,221	10,922	4,135	8,853	9,846	6,869	8,151
Standard Deviation	5,435	6,021	3,543	3,632	4,210	3,704	5,010	4,954
Total OJT Costs								
Linear Trainee Costs and Supervisor Costs	12,141	11,309	15,200	10,092	14,100	15,977	10,125	12,915
Standard Deviation	6,830	8,022	5,484	2,105	6,417	5,787	6,026	6,932
Piecewise Linear and Supervisor Costs	12,934	11,121	17,888	13,175	14,765	16,379	10,914	13,661
Standard Deviation	7,625	8,168	4,771	5,593	8,241	7,998	9,421	7,811
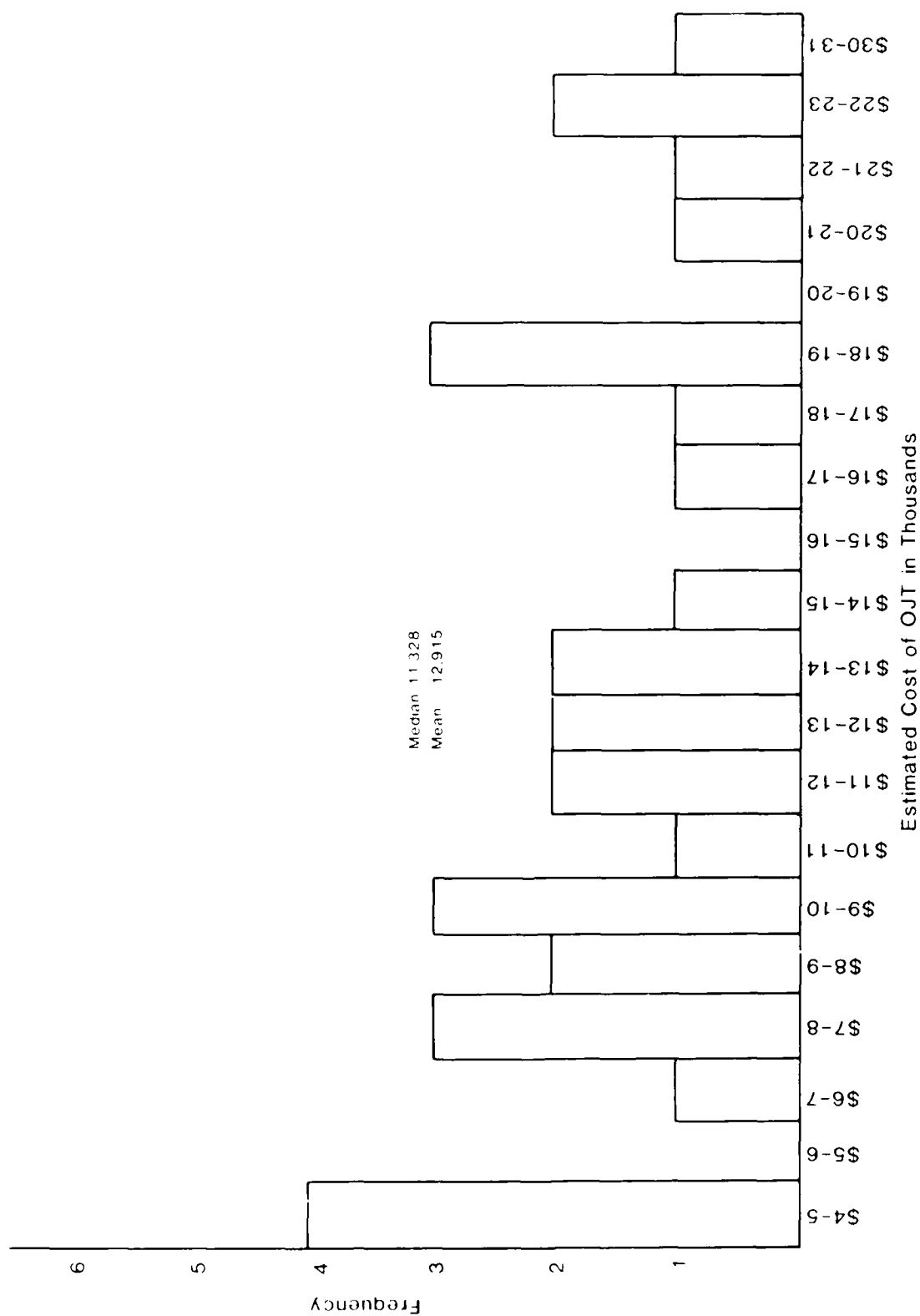
Figure 3. Distribution of OJT cost estimates.[a]

[a]Based on linear trainee time cost estimates.
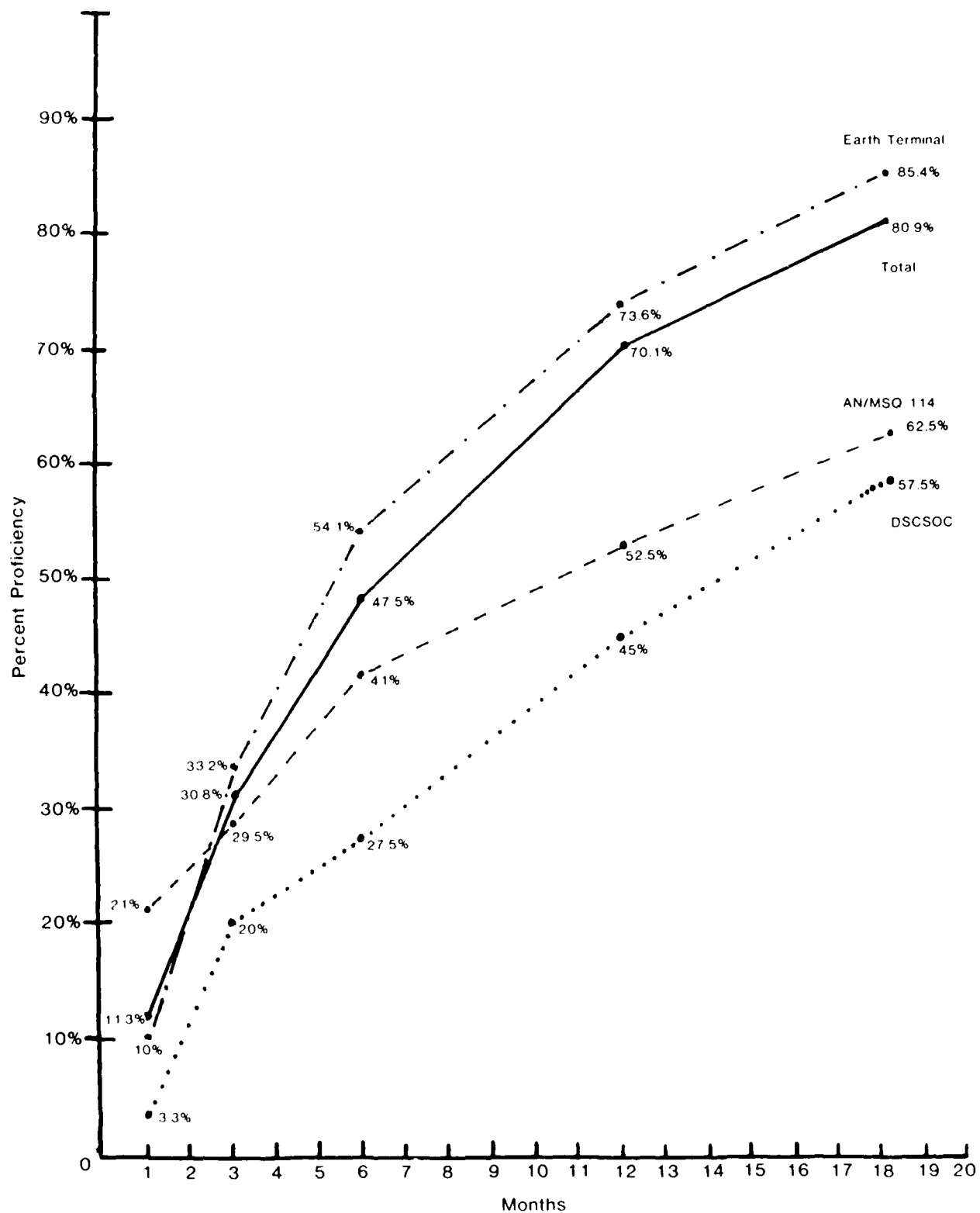
Figure 4. Learning curves for Fort Detrick by type of equipment.

The Camp Roberts results indicate a clear difference in the perceptions of military and civilian personnel. For both trainee and supervisor time cost elements the cost estimates of military personnel exceed those of civilian workers on the site. Figure 5 identifies differences in the perceived magnitude of the trainee time path to proficiency as the major factor producing this difference in cost estimates. While we cannot currently ascertain which view more correctly reflects reality, the table does identify variation in supervisor perceptions as a factor contributing to variance in OJT cost estimates at Camp Roberts.

OJT cost estimates varied between the two installations. The estimated per trainee cost of OJT for Camp Roberts was $14,100 compared with $12,141 per trainee for Fort Detrick.[56] Obviously, the equipment and personnel manning differences alluded to above contribute to this variance. Greater civilian involvement in supervision of training at Camp Roberts than at Fort Detrick contributed to the differential in supervisor time costs in that the relevant segment of the GS salary scale exceeds that of military personnel. Differences in average time to proficiency account for the lion's share of differences in trainee time costs. For Fort Detrick the average estimated time to full proficiency in MOS 26Y was 18.3 months while at Camp Roberts it was 20.8 months. This difference becomes sizeable when translated into dollar amounts. Our interviews at the installations raised interesting reasons for this difference, reasons which will be discussed more fully later. It was suggested that at Camp Roberts more experienced civilian personnel tend to handle the bulk of major repair and maintenance work. As a result military personnel fail to gain experience as quickly as they would in the absence of the civilians. It was also suggested that because of its civilian strength, Roberts receives a different complement (quality) of new trainee than do some other installations. The example given was the seemingly large number of 26V's (Strategic Microwave Systems Repairer), 26R's (Strategic Satellite/Microwave Systems Operator), and 32D's (Station Technical Controller) functioning in 26Y slots at Camp Roberts. Having less formal satellite training these individuals naturally gain competence at a slower rate, raising average 26Y OJT costs.
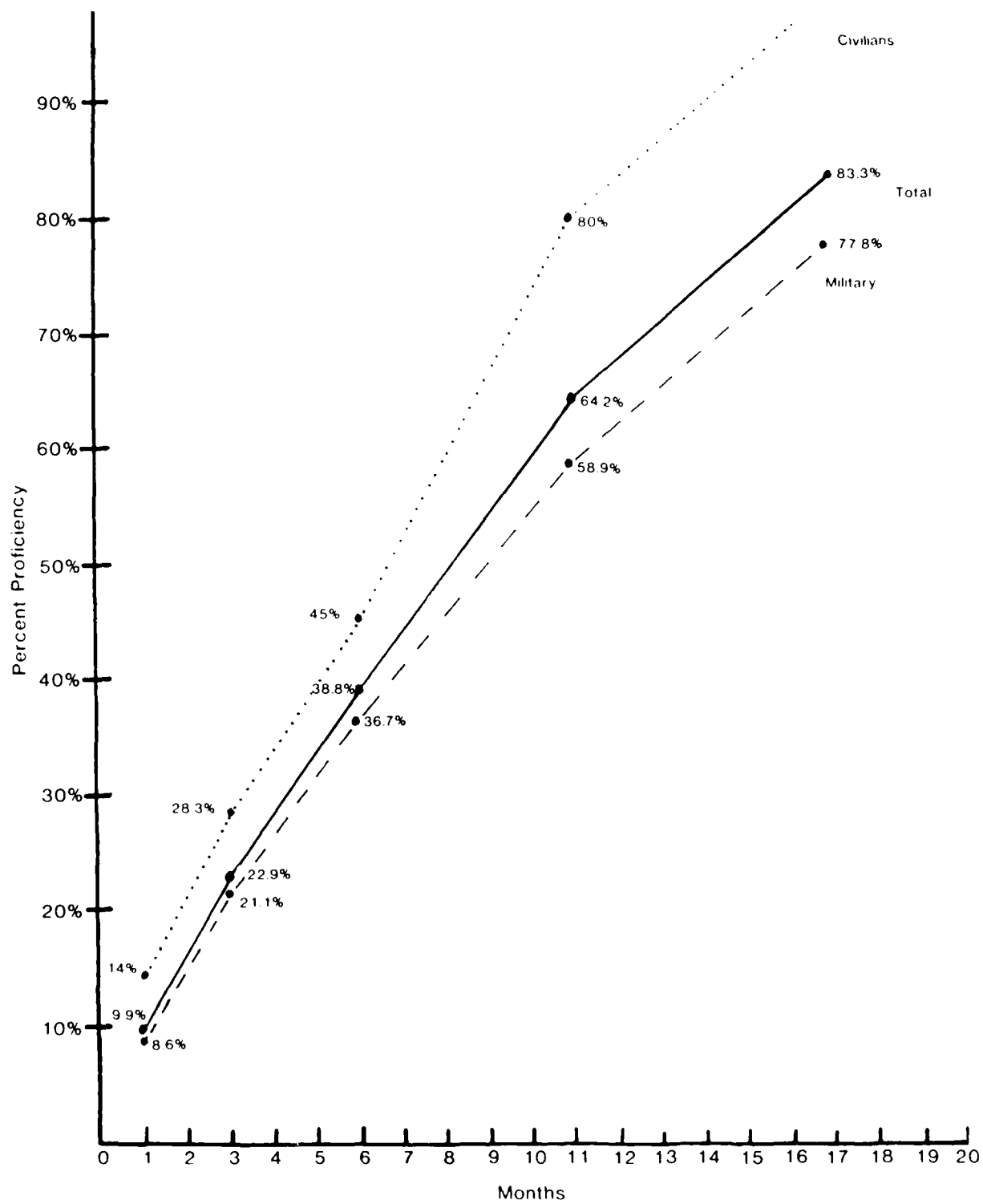
Figure 5. Learning curve for Camp Roberts by type of personnel questioned.

Descriptive statistics intended to summarize responses to selected questions of the survey instrument are presented in Table II. The mean value for Question 4 implies that the average time to proficiency in MOS 26Y (as defined in the questionnaire) is 19.3 months after entry to the unit. The supervisors sampled believed the top 20% of new trainees could attain proficiency in an average of 10.5 months (Question 5) and that the average E5 to E7 at their work site was 71.7% proficient by our definition.

Nearly 97 percent of those surveyed responded "yes" to Question 7 which asked if the unit would be able to perform its mission and maintain effectiveness if all OJT trainees (E1-E4s) were removed from the unit. A positive response to this question can be interpreted as implying that trainees do not contribute to unit productivity and that trainee time is therefore entirely a training cost (i.e., there is no production cost-training cost division).[57] Assuming that trainees make no contribution to production during training significantly increases estimated trainee time costs. Table I indicates that when this assumption is made, estimated trainee time costs of OJT increase from $4764 to $19,334 per 26Y trainee. Similar to Question 7, Question 9 sought information on the presence of supervisor slack time. One hundred percent of the respondents answered "No" to this question. This indicates that supervisors had duties in the work area requiring their presence even if OJT ceased. Consequently their number could not be reduced even if all training ceased. Accepting this as a valid response implies that supervisor OJT costs are zero. Thus total OJT costs become purely trainee time costs.

Responses to Question 10 were the foundation upon which the piece-wise linear estimate of trainee time costs was built. As mentioned earlier, cost estimates using the piece-wise linear technique exceeded those based on a linear approximation of the proficiency curve (Table I). Figures 6 and 7 compare the linear and piece-wise linear proficiency curves for the two installations surveyed.

Table II: Summary Statistics for Responses to Selected Survey Questions

| Question Number	Content of Question	Fort Detrick Mean	SD	Camp Roberts Mean	SD	Both Installations Mean	SD
1.	AIT: Entry Proficiency (%)	18.2	16.6	13.8	9.3	16.3	13.8
4.	Months to Proficiency	18.3	7.5	20.8	9.0	19.3	9.3
5.	Months to Proficiency for Top 20% of Trainees	10.2	4.8	10.9	5.7	10.5	4.9
6.	Proficiency of average individual on site (%)	80.8	14.1	58.5	14.5	71.7	17.9
7.	With no trainees, could unit maintain						
	effectiveness?	100% yes		92.3% yes		96.9% yes	
9.	With no OJT responsibility, could reduce						
	E5-8s?	100% no		100% no		100% no	
10A.	Proficiency after 1 month in unit (%)	11.3	14.3	9.9	12.4	10.8	13.3
10B.	Proficiency after 3 months in unit (%)	30.8	14.6	22.9	13.4	27.5	14.4
10C.	Proficiency after 6 months in unit (%)	47.5	22.0	38.8	19.0	44.0	21.0
10D.	Proficiency after 12 months in unit (%)	70.1	23.4	64.2	25.1	67.7	23.9
10E.	Proficiency after 18 months in unit (%)	80.9	22.1	83.3	23.9	81.9	23.0
11A.	OJT time after 1 month in unit (%)	89.5	14.2	90.3	11.0	89.9	27.3
11B.	OJT time after 3 months in unit (%)	71.3	15.8	85.0	14.3	77.4	15.5
11C.	OJT time after 6 months in unit (%)	55.7	12.9	60.8	17.0	58.0	24.3
11D.	OJT time after 12 months in unit (%)	34.7	18.9	39.6	21.7	36.8	19.7
11E.	OJT time after 18 months in unit (%)	20.3	19.1	27.9	20.9	23.7	20.7
12ai.	E5s with weekly OJT role (#)	3.1	1.8	3.8	1.0	3.4	1.5
12aii.	E6s with weekly OJT role (#)	2.0	1.1	1.2	.7	1.7	1.0
12aiii.	E7s with weekly OJT role (#)	1.3	.8	.7	.4	1.0	.7
12aiv.	Warrant officers with weekly OJT role (#)	.7	.5	NA	NA	--	--
12av.	Civilians with weekly OJT role (#)	NA	NA	2.8	1.4	--	--
12bi.	E5 OJT time involvement (%)	58.1	31.6	42.1	15.1	51.7	27.1
12bii.	E6 OJT time involvement (%)	56.7	30.0	30.0	15.4	46.0	27.2
12biii.	E7 OJT time involvement (%)	30.6	31.1	18.1	11.9	25.4	25.6
12biv.	Warrant officer time involvement (%)	11	11.4	NA	NA	--	--
12bv.	Civilian time involvement (%)	NA	NA	20.4	7.8	--	--
12c.	Supervisor weekly hours	49.8	5.3	40	3.3	45.6	13.7
18.	Daily maintenance and repair (%)	48.2	14.1	29.1	24.8	41.2	20.8
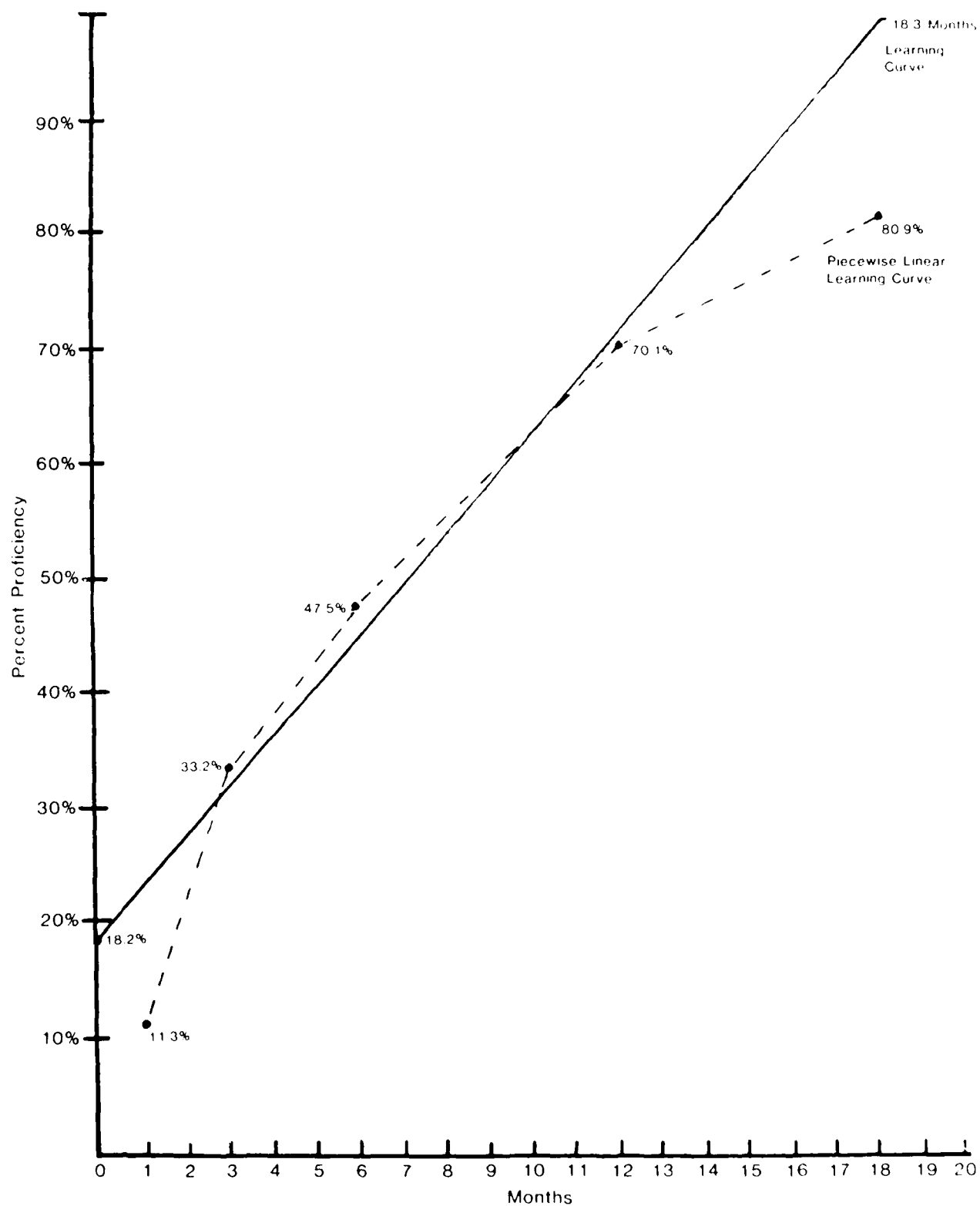
Figure 6.   Fort Detrick: Comparison of linear and piecewise linear learning curves.
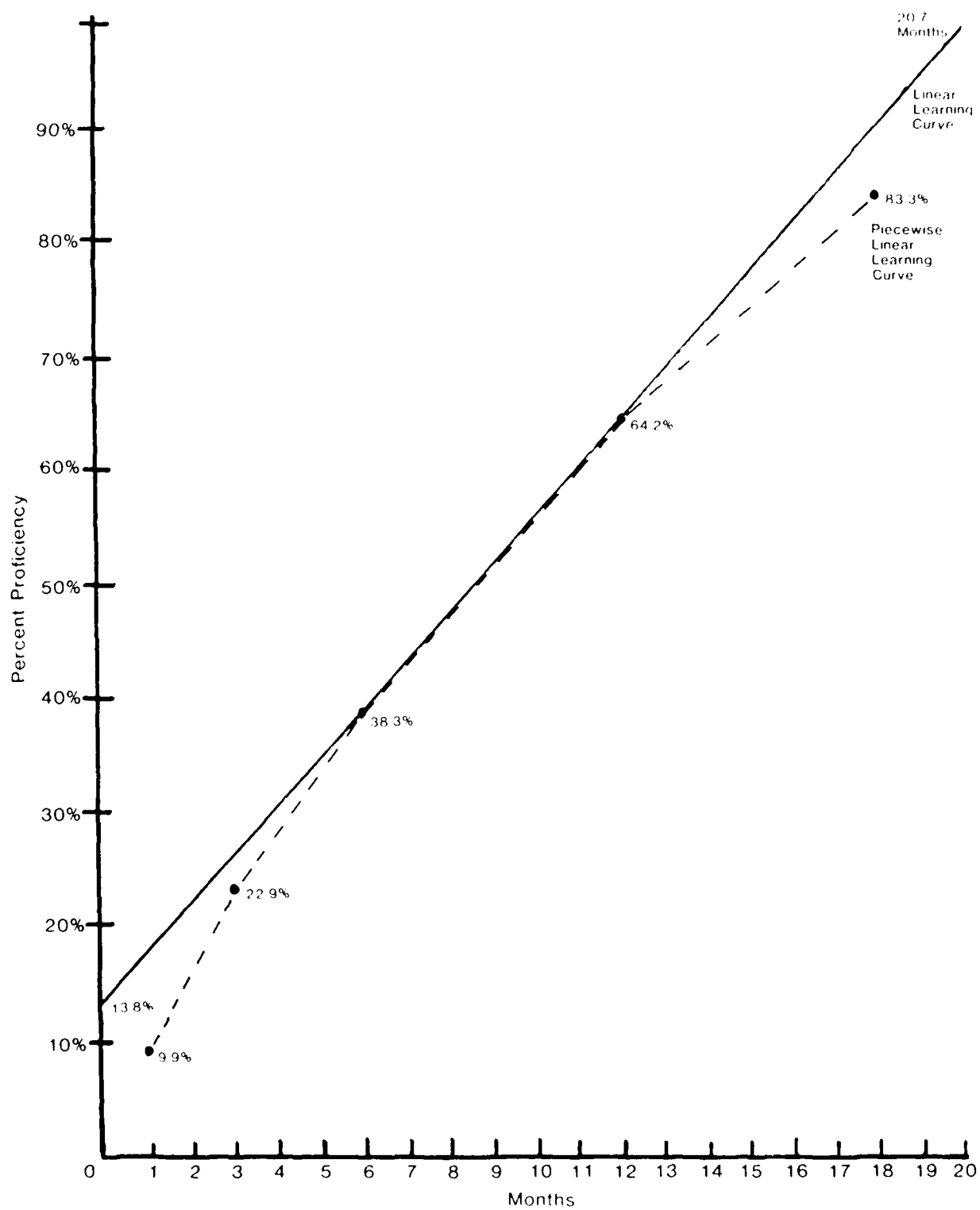
Figure 7. Camp Roberts: Comparison of linear and piecewise linear learning
curves.

Sensitivity Analysis

This section briefly considers changes in the estimates of the two OJT cost elements which would result from changes in some key variables. A key variable in both cost equations is the number of months of OJT required for full proficiency. Changes in this variable would have a profound impact on the cost estimates. For example, a month increase (decrease) in the time required to reach full proficiency would increase (decrease) the average estimate of supervisor time costs at Fort Detrick by 5 percent, from $7708 to $8104 ($7312).

Another key variable influencing the magnitude of the supervisor time cost estimate is the number of OJT trainees on the site since total supervisory time costs must be spread over the relevant number of trainees in order to calculate per trainee supervisory costs. This is demonstrated using data from Camp Roberts. A 20 percent decrease in the number of OJT trainees on site at Camp Roberts would increase the supervisor OJT cost estimate 29 percent from $8,853 to $11,383, all else being equal. (It could well be that changing the supervisor-trainee ratio would alter time to proficiency.) Doubling the number of trainees would reduce supervisor costs per trainee by more than 50 percent, ceteris paribus. This sensitivity makes correct determination of the instructor to trainee ratio a critical goal of any survey instrument investigating OJT costs. A third key variable in the supervisor cost equation is the dollar value assessed to each time unit of supervision. Choice of a proxy from comparable civilian sector occupations would have significantly increased the OJT cost estimate.

A third important element has been discussed earlier--the amount of actual production the trainee produces in the course of training. This point is reiterated using the data in Table I. Assuming the trainee produced no positive net output during training yielded an average trainee time cost of $19,334 across the two bases surveyed. Valuing output produced during OJT lowered this estimate to $5509 under one estimation formula and $4764 under another. Obviously the position and "steepness" of the trainee productivity curve is a major variable in the magnitude of OJT cost estimates.

Beyond the Cost Estimates: Larger Issues

Raised by the Interviewees

It is important to recognize what the cost estimates derived above do and do not measure. They attempt to measure OJT costs, given the current very specific and particular arrangements for organizing the labor allocation and training process within MOS 26Y. Under different specific arrangements, OJT cost estimates might be quite different. This obvious point is important because there was a good deal of sentiment among the interviewees that current MOS 26Y arrangements are in need of considerable change and improvement. A distillation of those interviewee comments is presented below. We believe they contain information which needs to be thoroughly considered by those responsible for labor allocation and training within MOS 26Y. The interviewee comments are divided into three broad categories: (1) given the existing classroom-OJT system, how is the labor allocation mechanism which assigns individuals to MOS 26Y slots working?; (2) how might "advanced individual training" (the pre-OJT stage of training at Fort Gordon) be changed?; and (3) what factors influence the amount and quality of OJT given by the current system?

How is the System for Allocating Individuals to 26Y slots working?

A number of possible problems with the current allocation system were identified in the course of our interviews. First, many of the individuals assigned to 26Y slots at Camp Roberts had training in other MOS's, but not in 26Y. Often someone trained in MOS 26V (microwave communications) was assigned to Camp Roberts in a 26Y slot. While a subset of these individuals had received a special transition course at Fort Gordon to prepare them for 26Y duties, many of the trainees received no such training. Supervisors who commented on the situation were virtually unanimous in indicating that such assignment without transition training was highly inappropriate and wasteful. The 26V's were totally at a loss when they arrived, many found it impossible to make the adjustment, and even those who did adjust imposed very high training costs. In addition, many potentially productive trainees were totally

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turned off to the military by this treatment. When asked why they thought 26V's were sent to take 26Y slots at Camp Roberts, some interviewees suggested that there was a current shortage of 26Y's (and an excess of 26V's) and available 26Y's were assigned to higher-need locations. Camp Roberts could "make-do" with 26V's because civilians did much of the repair work at Camp Roberts (this will be discussed below). Thus, Camp Roberts became a "dumping ground" for 26V's assigned to duty in MOS 26Y. Because there are so many 26V's at Camp Roberts, our cost estimates no doubt reflect, in part, the extra cost of training 26V's in satellite communications using OJT.

A second difficulty concerns allocation of repair functions between civilian personnel and MOS 26Y military personnel. At Camp Roberts, but not necessarily at other bases, civilians do the lion's share of the repair and complex maintenance work. This means that most military personnel function as operators not repairers. This leads to a number of difficulties. First, individuals who entered 26Y to become repairers do not get much opportunity to function as repairers, leading to considerable dissatisfaction. Second, because the civilians do the repairing, it was claimed by some interviewees that the military trainees at Camp Roberts never received much repair OJT. If the individual is later sent to a base without civilian staff where he is expected to make repairs, he lacks the training. Others at Camp Roberts argued that the presence of civilians was not an insurmountable obstacle to obtaining training, (this is discussed further below) but that the shortness of average trainee stays was. Trainees apparently average about 8 months at this site, whereas the more experienced military supervisors and civilians believed it took much longer to become really competent at repairing equipment.

The notion that some MOS 26Y personnel function only as operators rather than repairers leads to a third allocation issue. Several senior interviewees argued that there might be a considerable gain in dividing MOS 26Y into two separate MOSs, one involving operator duties, the other involving repair responsibilities.[58] This would have several advantages. First, it would avoid the bad morale generated by giving someone a

"repairer" title but never teaching them repair. Second, it would avoid the current difficulty that two E5 26Y's are not necessarily close substitutes; depending on their particular experiences, one may be a skilled repairer and the other be unable to repair anything. This makes it hard for authorities to allocate appropriate individuals to particular slots at particular locations. Third, it would allow use of reenlistment as a requirement to get into the more skilled repairer MOS, thereby avoiding at least in part the loss of skills when a well-trained first-term enlistee does not re-enlist.

A fourth difficulty involves reenlistment and external market considerations. On the one hand, many interviewees argued that many of the most talented 26Y's do not reenlist because the civilian wage they can get in related electronics jobs is so much higher than their military pay. If many of the best and most promising trainees are in fact leaving, this suggests examining policies to stem the flow. On the other hand, we were also told that in recent months there have been limits placed on available reenlistment slots, so that competent 26Y's who want to reenlist may be unable to do so.

A final difficulty mentioned by supervisors is the system's inability to weed out individuals who cannot function competently in the MOS. It is claimed that (1) the Fort Gordon school no longer systematically weeds out such individuals (this is discussed further below); and (2) it is very difficult to base promotions on technical competence in the MOS. Obviously, to the extent there is merit in these claims, OJT costs using our estimation methods will be higher than if less competent individuals were weeded out.

Criticisms of the Pre-OJT Stage of Training

The length, cost and effectiveness of OJT depends in part on the level and effectiveness of classroom training received by the trainee before he arrives at his unit. Interviewees had a number of comments about this pre-OJT training given currently at Fort Gordon. One kind of complaint stressed specific omissions in the curriculum at Fort Gordon. A frequent complaint was that trainees at Fort Gordon were not effectively instructed in the use of test equipment. Use of such devices is essential in diagnosing and repairing equipment problems. Another frequent complaint

was that the training at Fort Gordon did not provide enough "hands-on" experience operating and repairing equipment. Other complaints went beyond specific omissions to critiques of the general approaches used at the training school. Several senior interviewees argued that firm grounding in general electronics theory would be extremely valuable, but was *not* provided. Instead, what was taught was how to replace modules, not the theory behind what the modules do. One interviewee described the training program contents as "guesswork troubleshooting." Others pointed out that preventive *maintenance-type concerns* were not taught.

Besides problems of course content, many interviewees stressed difficulties stemming from equipment mismatches. Individuals would be trained on one piece of equipment at Fort Gordon, only to be assigned to a quite different piece of equipment in the field.[59] Some interviewees claimed that some instructors had no actual experience at operational sites before they started teaching. Finally, there was a strong perception among senior interviewees that there had been a large decrease over time in the quality of graduates from Fort Gordon. Some claimed that this resulted from some combination of the following: changes in curriculum content, a shift to "hard-to-fail" open book exams, a change in school philosophy towards a view that very few individuals should ever fail to pass the school courses, and a growing demand for 26Y's in the field.

What Factors Influence the Amount and Quality of OJT in the Current System?

Understanding determinants of the current amount and quality of OJT is important for at least two reasons. First, our OJT cost estimates result from the current very specific and particular arrangements for organizing MOS 26Y work and training. Understanding the determinants of the current amount and quality of OJT also provides insight into determinants of OJT costs, and can be used to infer how costs might change if particular determinants shifted. Second, knowledge of these determinants might indicate useful ways to change the OJT process. While we are only reporting interviewee opinions, these opinions may contain useful views of the OJT process.

Our interviews revealed a number of factors which were perceived as

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affecting the amount and/or quality of OJT provided. One important factor seemed to be the presence of a civilian repair and maintenance staff. At Camp Roberts, for example, civilian staff seemed to have the major responsibility for maintenance and repair. The presence of such a staff is likely to influence the volume of OJT. First to the extent that maintenance and repair is no longer seen as primarily a military personnel function, military personnel will not automatically receive training in it as a matter of course. Second, if the training is not given as a matter of course, then the extent to which repair training takes place will depend on particular attitudes ("willingness") of the civilians, their relationships to the senior military technicians, and the desire and ability of senior military personnel to "push" the civilians to aid in training. Third, if most civilians work day shift and the military personnel work varying shifts, training relationships cannot be easily maintained. A second factor affecting the quantity of OJT has already been mentioned: the average length of stay of a trainee at a site. If it is known to both trainees and trainers that the typical trainee will stay for less than a year, the trainee sees his learning opportunities as limited, and the trainer sees that his unit will not benefit for long from the trainee's gain in proficiency. Consequently the incentive to provide "deep" training is lessened. Interestingly, several of the most respected technical experts we interviewed indicated that it had been the chance to stay at one site for four or five years which had resulted in obtaining real expertise.

A third factor affecting the quantity of OJT is the level of personnel availability on each shift. On the one hand, it would seem that the presence of large numbers of senior personnel allows some to concentrate their effort on supervision of training. The interviews suggest that there is a subtle but possibly very important factor working in the opposite direction. Several supervisors indicated that they had received some of their most valuable training when they were working in situations short of personnel. In such situations, when something broke, people with less experience had to be involved in trying to fix it. While this may have led to less expeditious repairs and more down time, it led to

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more and "deeper" OJT. Stories with similar implications came from personnel who, after a stint at a place like Roberts or Detrick, were sent to an overseas post where junior 26Ys had to be responsible for fixing whatever went wrong. This was where (the interviewee claimed) they _really_ learned to repair things.

A number of other factors were mentioned as affecting the quantity and quality of OJT. First, several commenters argued that there had been serious deterioration over time in the quality of technical manuals (TM's) available to trainers and trainees. Since the more highly motivated trainees could often learn from self-study of TM's, they claimed inadequacy of recent TM's would hinder the learning process. It was further claimed that an important source of deterioration was the attempt to write the manuals in "too-simple" ("too low reading level") English, and to omit much of the material that would formerly have been included. Second, OJT time itself depends on the quantity of "mission-oriented" time versus "other military duty" time. In some locations, more time is spent on "other military" activities -- parading, groundkeeping, military tactics, etc. -- than at other sites. This affects OJT time, and is an example of what some interviewees saw as a tension between technical duties and "other military" duties. This tension was sometimes described by the phrase "are we soldiers first or technicians first?"

A final determinant deserves special mention because it raises what seems to be a quite general dilemma about the tradeoff between more output in the short run and more training in the short run (perhaps allowing more output in the long run.) Several interviewees indicated that, in the past, there had been allowance made for regularly scheduled down time for maintenance of the equipment. This permitted trainees to participate in regular maintenance and repair activities. This practice was discontinued, and there has apparently been growing stress on higher and higher performance standards. That is, sites are expected to keep their signals in operation (without down-time) virtually constantly. Any down-time requires special reports to several higher authorities, and is frowned upon. This growing stress on reliability inhibits the ability and incentive of sites to train. Training -- allowing trainees to attempt to have hands-on

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experience maintaining and repairing equipment -- increases the short-run probability of mistakes and extra down time. Thus, growing emphasis on short-run reliability inhibits the provision of training.

SOME IMPLICATIONS FOR THE FOCUS AND DESIGN OF FUTURE OJT STUDIES

A number of inferences can be drawn from this pilot study about how future OJT costing studies might be focussed and designed. A first set of findings concerns how this pilot study might be expanded into a full-scale study of OJT costs. Such a study would not consider broad questions of labor allocation and occupational design and boundaries (such as those raised in the prior section); instead, it would focus narrowly on the actual OJT costs generated by the current occupational definition, labor allocation and training arrangements.

As one possibility, the pilot might be expanded by doing a larger sample survey study of MOS 26Y. If such a study were to be undertaken, at least two preparatory tasks would be included. First, the questionnaire would need to be modified to take account of shortcomings discovered during our interviews and analysis. Appendix 3 discusses the kinds of changes needed in the questionnaire. Second, it might be useful to develop techniques for estimating the cost elements omitted from the pilot study, such as (1) the per-trainee cost share of all administrative costs associated with assigning trainees to OJT slots, and any costs of developing and distributing special training materials; (2) the per trainee share of costs of equipment "wear and tear" due to the training itself; and (3) the per-trainee cost of materials used up in the training process. Accurate estimation of these cost elements would seem to require access to accounting data records in addition to the type of supervisor interviews used in this pilot study. Supervisors at the training site cannot be expected to have any information about many of these other cost items.

If these additional sources of costs are to be investigated, the effort should start with a detailed review of the Dunham and Eisele studies, both of which attempted to estimate some of these cost categories. While producing complete estimates does require that these costs be

included, it must be recognized that the effect on cost estimates of including these items may not be large. Both earlier studies showed that these categories of costs accounted for less than one-third of total costs.

Rather than just expanding the pilot to a full scale MOS 26Y study, a more ambitious undertaking would involve studying additional occupations. This would be attractive because it would generate results about the variation of OJT costs across types of occupations. The current authors believe that MOS 26Y, because it is a technically complex MOS, may generate training costs far higher than many other occupations. Studies of other occupations could confirm or refute this impression.

If the range of occupations is to be expanded, careful attention must be given to choosing the occupations. We believe that the very nature of OJT is likely to differ by occupation-type. One example involves direct combat occupations, such as infantryman or tank personnel, versus occupations not directly involved in combat (MOS 26Y would be one such occupation). In the "noncombat" MOS 26Y occupation, actual operations involving well-specified work tasks exist in peacetime; that is, the occupation's "mission" exists whether or not combat is taking place. This means that OJT can take place in actual (not simulated) work situations. In combat occupations, on the other hand, the occupation's "mission" is combat, but real combat is only available in wartime. Thus, OJT in peacetime cannot be based on "real" work situations--only simulated exercises are possible.

This stark contrast between the nature of OJT in combat versus noncombat occupations suggests that studies of combat occupations need different concepts (and perhaps different questionnaires) to study combat OJT. But within noncombat (or combat) occupations there may be other important distinctions among occupations. These distinctions must be ferretted out, and categories of occupations developed based on these distinctions, before a final list of occupations are selected for further study. We are not sure what the appropriate categories of occupations are, though we have toyed with a three-way distinction between combat, direct combat support, and administrative. Since MOS 26Y does not fit neatly into this scheme, we suspect a more complex set of categories is needed.

Our experience with the 26Y pilot study strongly suggests the following rules about proceeding with an expanded study. First, once an occupational category (such as "administrative") is established and an occupation or occupations fitting this category chosen, do at least one pilot study within each occupational category before doing the full-blown study. As part of each pilot, visit at least two bases. This rule of "at least one pilot, two bases" per occupational category is suggested by possible distinctive differences across occupational categories (and, within occupations, across bases). By doing a category-specific pilot, important situations and problems unique to that occupation or category of occupations can be discovered early and incorporated in the questionnaire for the full-blown study. This helps minimize the danger of important concepts requiring particular questions being discovered after the main body of interviews has already been carried out. The same logic is behind the suggestion that at least two bases be visited per pilot occupation.

A second rule based on our 26Y experience is that the study should not have one all-purpose questionnaire for all occupations. Because the nature of OJT is likely to vary by occupational category, we feel very strongly that, at the very least, questionnaires specific to the occupation category are needed. A questionnaire investigating OJT for an infantryman is unlikely to elicit the appropriate information for a satellite communications repair occupation, and vice-versa. Our third rule is that in early stages of any study questionnaires should be administered in person, not mailed to interviewees. The way in which our pilot was conducted allowed us to review the questionnaires with small groups of interviewees while the interviewees filled them out.
This technique allowed us to discover a number of ambiguities and differing interpretations of some of our questions. Without this direct contact with interviewees, our understanding of the meaning of responses to particular questions would be sorely lacking. Without such direct contact, the danger exists that meaningless responses will be used to reach spurious conclusions about costs.[60]

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Reliability Questions

Our pilot study is based on interviews with training supervisors. What can be said about the potential accuracy of the OJT cost estimates produced by such studies? At least four kinds of concerns come to mind: (1) the recall problem; (2) the supervisor seniority problem; (3) variation across bases; and (4) the occupational equilibrium question. The recall problem concerns whether a supervisor can in fact accurately recall the kinds of information about trainees required for the OJT cost questionnaire. In the absence of alternate sources of "learning curve" data on trainees, there is no way to definitively answer the question. There is one particular version of the recall problem that is subject to control through study design. An arguable (though unproven) hypothesis is that supervisors recall "memorable" (for example, very slow learning or very fast learning) trainees. If such memorable cases tend to dominate their memories, then questions asking for supervisor perceptions of average learning speeds may, in fact, get responses biased toward memorable cases. No one knows whether such a bias exists (or even its direction), but it could be controlled by redesigning the way in which costing studies are performed. What is needed is to obtain a random sample of trainees, link these trainees to the supervisors who trained them, and then administer the OJT questionnaire to the supervisors, asking them to answer questions about speed of learning with respect to particular named trainees. Such a procedure was followed in the Gay study. Obviously, carrying out such a study requires a much more elaborate set of prior information, planning and coordination than was available to us in our pilot study. For one thing, information linking supervisors to trainees must be collected and processed before base visits can be planned.

The supervisor seniority problem arose in our MOS 26Y study, but is likely to be relevant only in technologically complex occupations. The problem is that, from the point of view of more senior-ranked technicians (E-7's, for example), some of the supervisors (E5's, for example) are themselves not trained to full proficiency. Thus, asking an incompletely trained E-5 how long it takes to train an E-3 to "full proficiency" is likely to produce an answer which underestimates training time. To the

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extent that this is a real problem, it is less likely to arise in less complex occupations, where thorough training need not require extensive time periods. In occupations where it is a problem, one would look for danger signals by comparing training time estimates given by senior trainers to those given by trainers. If the time diverged in the direction suggested above, potential bias might be indicated.

Variations in OJT cost due to equipment differences or differences across bases can arise in almost any MOS. Equipment differences are obviously relevant in any repair MOS (different units may have quite different equipment to repair), but can also arise in other occupations. Artillerymen, at different locations, for example, may be responsible for equipment of quite different complexity. Equipment differences are one source of variance between bases, but not the only source. In MOS 26Y, for example, interviewees noted that bases varied in the amount of patrolling, parading, and grounds-cleaning required of technicians. The presence of differences across bases implies that an OJT costing study of a specific occupation must be designed to take account of possible variations across bases by including an appropriate number of bases in the study. If different equipment is expected to be a source of differences across bases, this needs to be specifically investigated by the researchers.

The occupational equilibrium question is in many ways the most intractable problem affecting the reliability of OJT cost estimates. Fortunately, however, it is unlikely to affect many of the occupations studied. The problem arises when an occupation is studied which is rapidly growing (or shrinking). If an occupation is rapidly growing, there are likely to be temporary shortages of trained personnel, perhaps leading to a bulge in the number of trainees. The combination of shortages of potential trainers, an excess of trainees, and demands to speed up training is likely to produce OJT arrangements (and OJT costs) which are different from those that would prevail in a nonshortage situation. Thus, OJT costs estimated for a rapidly growing (or shrinking) occupation may be atypical; such cost estimates would not represent a good approximation to training costs in normal situations.

Different Sources of OJT -- Classroom Training Complementarity

While the pilot study focussed on only one occupation, we did spend time thinking about and discussing with knowledgeable individuals what the possible sources of OJT requirements were. That is, given that training for many military occupations begins with a "formal" or "classroom" segment, what important training tasks, if any, are left to be done after formal training; that is, what (if any) distinctive training tasks are "left" for OJT, and why do they get "assigned" to OJT rather than formal training?

A major reason for tasks being left to OJT is that formal training and OJT are "complementary;" that is, there are payoffs in terms of return per dollar cost from combining formal training and OJT experiences for a specific trainee. Our discussions about OJT have turned up at least three sources of complementarity. It is our strong feeling that study of additional MOS's will turn up additional sources.

The first source of OJT-formal training complementarity results from initial (pre-training) uncertainty about post-formal training assignment of a particular trainee. Suppose an individual is to be trained in an MOS focussing on vehicle repair. If the training school authorities knew before formal training commenced what task (for example fixing M-1 tank brakes) the individual would be assigned after training, they could train to that task. Typically, however, post-training assignments are not known. Thus, the training school will teach quite general skills, while OJT at the unit level will involve teaching the individual all the particulars and idiosyncracies of repairing M-1 tank brakes. This source of complementarity seems peculiar to the military; in the private sector of the economy, for-profit firms would typically economize on specific training costs by focussing the training on the tasks the individual would actually perform.

A second source of OJT-formal training complementarity is a phenomenon called "unit training" (as contrasted with "individual training"). The distinction seems particularly appropriate for combat occupations. In that context, an example of individual training would be learning to use (fire and maintain) a rifle. "Unit" training would involve learning all the coordination and "teamwork" skills needed to get the entire unit

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deployed and functioning in a coordinated way in combat or simulated combat situations. Developing this coordination is only possible once the individual is ensconced in an actual operational unit.

A third source of OJT-formal training complementarity applies to the particular case of MOS 26Y, and results from capital (equipment) "scarcity." Becoming a fully proficient Communications Satellite Ground Equipment Repairer requires learning to repair various possible malfunctions of complex and expensive satellite tracking equipment. The formal school that trains individuals in MOS 26Y has limited amounts of the relevant equipment. These equipment limitations result from the very high cost of extra units (as one example, a particular terminal used historically for all MOS 26Y training costs around $5 million per unit). Given numbers of trainees versus equipment availability, two possible shortcomings of formal training emerge. First, there may be too little time for each trainee to practice basic maintenance and frequent repair procedures. Second, there are malfunctions which happen only infrequently, i.e. malfunctions which may not happen while the trainee is at the school. Both of these deficiencies can be remedied by further "hands on" experience with the machine at the actual satellite tracking unit after formal training. Thus, this OJT-formal training complementarity stems from equipment scarcity, and is conceptually quite different from the other two sources previously identified.

We would reiterate that studies of additional MOS's are likely to turn up additional sources of formal-OJT complimentarity.

Is the Current Level of OJT and Classroom Training Appropriate?

Perhaps the most fundamental issue in evaluating the significance of any specific estimates of OJT cost for a particular occupation concerns whether the OJT and classroom training arrangements generating those costs are "appropriate." That is, any OJT cost estimate is a function of the current level and mix of OJT and classroom training, and the "quality" of each component. If either OJT or classroom arrangements are inadequate -- that is, considerably below the Army's own ability to construct and implement a well-designed and well-functioning system--then the OJT cost

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estimates produced may have limited usefulness. The real issues that the Army should be focussing on in this case are: (1) "How do we improve the training arrangements?"; and (2) "How would these improvements be likely to change OJT costs?".

Our experience with MOS 26Y suggests two important instances of this broad issue. First, in MOS 26Y, the amount, focus, and quality of classroom training seems to affect the required amount of OJT. Better and more appropriately focussed classroom training seems likely to reduce "time to full proficiency." At the operational unit, reductions in time to proficiency directly reduce the volume and cost of OJT needed. Second, the question of "how to better design and organize classroom training and OJT" really does seem to be a very important issue in MOS 26Y. Our interviews repeatedly reveal that current supervisory personnel strongly believe that current training arrangements are far from adequate. That is, there is circumstantial evidence that redesigning the training process might result in higher quality trainees at lower cost. This possibility rather than our specific OJT cost estimates, may well be the most important result of our pilot study.

Given this kind of finding about MOS 26Y, an important implication for future research is that researchers studying OJT costs need to be sensitive to the possibility that current training arrangements in a particular MOS may be inadequate. If there is any substantial circumstantial evidence that this is the case, this evidence needs to be prominently displayed in the researchers' reports. Moreover, the Army needs to deal with such evidence in a serious way. This would involve devoting significant attention to the question of whether revised training arrangements are possible and desirable. It would also involve treating any specific OJT cost estimates with the appropriate degree of skepticism suggested by evidence on inadequate training arrangements.

Footnotes

*   The authors are respectively Professor of Economics, The George
    Washington University, and Assistant Professor of Management and
    Human Resources, Ohio State University.

1. Weiher, Rodney and Horowitz, Stanley A. "The Relative Costs of
    Formal On-the-Job Training for Navy Enlisted Occupations"
    Center for Naval Analysis, Professional Paper #83, November 1971.

2. ibid., Weiher and Horowitz, p.2.

3. Sample size for the individual ratings ranged from a low of 3 to a
    high of 132 observations.

4. ibid., Weiher and Horowitz, p.7.

5. ibid., p.16.

6. Gay, Robert M., "Estimating the Cost of On-the-Job Training in
    Military Occupations: A Methodology and Pilot Study," Rand
    Corporation, R-1351-ARPA, April 1974, identifies another potential
    problem in the Weiher and Horowitz study. In particular, the
    finding of higher costs to all OJT training may result from:

            "The two groups (being) comparable in OJT
            performance and differences in performance on
            the written exam reflect(ing) a positive
            correlation between formal schooling and
            the ability to take written tests." (p.48)

7. Arzigan, Simon On the Job Training Costs: An Analysis, U.S. Navy,
    Bureau of Naval Personnel, WRM 67-52, Washington, D.C., June 1967.

    We have been unable to locate a copy of this study and include it in
    the literature review. Arzigan's study is important for having
    demonstrated the basic methodology followed later by Weiher and
    Horowitz, and others. His estimates themselves suffered from
    extremely poor data.

    He defined four categories of occupational specialties:
    technician, mechanic, operations, and support and then assigned
    an estimated apprenticeship period to each -- 36, 30, 24, and
    12 months, respectively. Arzigan then made the simplifying
    assumption that the percentage of time the trainee devotes to
    training declines at a constant rate from 100% in the first
    month of apprenticeship to zero percent in the last month.

This assumption was taken to imply that a trainee's effectiveness increases linearly from his/her departure from basic training through the completion of the apprenticeship period. Consequently the cost of trainee time was defined as the percentage of time spent in OJT during the month times the trainee pay rate. With respect to supervisor costs Arzigan assumed the supervisor spent 5 percent of his time per month in OJT instruction. He valued (priced) this time at the average of the E-6 and E-7 pay grades.
(Summary is derived from assorted discussions of this study in subsequent research pieces and from conversations with individuals familiar with Arzigan's work).

8. Dunham, Alan D. "Estimated Cost of On-the-Job Training to the 3-Skill Level in the Communications Center Operations Specialty," Personal Research Division, Air Force Human Resources Laboratory, June 1972.

9. ibid., Gay, p.44.

10. op.cit., Dunham, p.1.

11. For a more detailed description of these categories and a comparison of trainees in the two training modes see Lecznar, William B., "The Road to Work: Technical School Training or Directed Duty Assignment?" AFHRL, April 1972.

12. The specific skills and the information to be completed by the respondent are shown below:

Skill	Weeks to Proficiency	Trainee hours per Week Reading	Trainee hours per Week OJT	Instructor Hours per Week	Trainees per Instructor
1. Mission					
2. Communications Security					
3. Safety					
4. Publications					
5. Supervision & Training					
6. Typing	- - -	- - - NOT APPLICABLE - - -			- - - -
7. Communications Instruction - General					
8. Cryptographic Operations - (only what's in CDC)					
9. DCS Teletype and Autodin Tributary Operation					
a. Routing					
b. Services					
c. Traffic handling					
1) Incoming Narrative Data					
2) Outgoing Narrative Data					
10. DCS Teletype and Data Relay Station Operation					
a. Torn tape operation					
1) Inspection					
2) Processing					
3) Routing					
4) Transmission					
b. Autodin Switching Center Operation (that which a 291X0 is responsible for)					
11. Weather Relay Operation					
12. Telephone Switchboard Operations	- - -	- - - NOT APPLICABLE - - -			- - - -

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13. op.cit., Gay, pp.44-45.

14. op.cit., Dunham, p.6.

15. ibid., Dunham, p.6.

16. ibid., Dunham, p.6.

17. ibid., Dunham, p.7. Dunham based this conclusion on the fact that scores
    on the Specialty Knowledge Test (SKT) revealed no statistically signifi-
    cant differences in performance for OJT and technical school trainees.

18. ibid., Dunham, p.7.

19. ibid., Dunham, p.8.

20. op.cit., Gay, p.45. This problem may be limited to the Air Force
    since it alone has a truly formalized OJT program. ·

21. Gay, Robert M., "Estimating the Cost of On-the-Job Training
    in Military Occupations: A Methodology and Pilot Study," Rand
    Corporation, R-1351-ARPA, April 1974.

22. ibid., Gay, p.60.

23. For further detail see Gay pp. 11 and 12. In defending assumption (3),
    Gay argues that, at reenlistment following the first tour, individuals
    "are fully trained but have not yet assumed significant supervisory re-
    sponsibilities. Also, the military is competing with civilian employers
    at this point and has an incentive to make military pay equal to military
    productivity to retain trained personnel." (p. 11.)

24. This potential source of variance had been suggested earlier by
    Weiher and Horowitz.

25. ibid., Gay, p.18. The individual trainee approach yielded an estimate of
    $6599 per trainee compared with $5499 using the typical trainee approach.
    In comparison to the $6400 net investment not recouped by the end of the
    first enlistment using the typical trainee approach, the individual
    trainee approach produced a $7600 average net (unrecouped) investment.

26. Region of residence was included in the Gay equation to proxy differences
    in the quality of education. It was originally included because it had
    proven significant in other studies explaining earnings differentials.
    These findings suggest the impact of region of residence on earnings

to lie elsewhere than through a productivity link. Inclusion of
race as a variable is discussed by Gay p.32-33.

27. Samers, Bernard N., Dunham, Alan D., Nordhauser, Fred, "The
    Development of a Methodology for Estimating the Cost of Air
    Force On-the-Job Training," Air Force Human Resource Laboratory,
    July 1974.

28. Samers provides an interesting list of why OJT cost estimates
    might be useful. These include use in:
    1. selection of optimal OJT/technical training mix
    2. lifecycle costing of weapon systems
    3. selection of specialties for the reenlistment
        bonus program
    4. evaluation of the dollar impact of changes in
        OJT course curriculum

29. Note should be taken of Dunham's active involvement in the
    Samers' study.

30. This additional question took the following form:

16. Based on your experience and, if you feel you need help, the experience of
other qualified personnel in your office, list the average number of productive and
non-productive hours of work for the trainee upgrading to the 3 level for each week
between start of t.aining and award of skill level. For instance, In the fourth week
of training your trainee spent approximately 30 hours receiving instruction and reading
and 10 hours doing productive work. Your second entry would look like this:

　　　4　　　　　　　　　　$\boxed{1}\boxed{0}$　　　　　　　　$\boxed{3}\boxed{0}$

Note that the hours for each week must sum to 40.

Weeks of Training (to the 3-level)	Trainee Productive Hours per Week	Instruction & Reading Hours per Week
1	☐☐	☐☐
4	☐☐	☐☐
8	☐☐	☐☐
12	☐☐	☐☐
16	☐☐	☐☐
20	☐☐	☐☐

(Samers p. 48.)

31.

17. For every 702X0 enlisted grade through E5 in your office for whom you have an AF623 on file, provide the following information (if available):

| Social Sec. Number | AQE Score | | | | Educ. Level | Date Entered 3 skill Training Day/Mth | Date AFSC Award Day/Mth | Method of Training (Check one) |
	Mech.	Admn.	Gen.	Elect.				OJT T.Schl

32. ibid., Samers, p.11.

33. These results highlight a number of potential tradeoffs in the selection of a survey approach. Samers gave major importance to the question of recall. His endorsement of the Self Reporting Approach reflects that concern for this approach was determined superior to the others, "depending the least on recall" (See Samers p. 14.)

34. Samers, Bernard N., Dunham, Alan D., and Nordhauser, Fred, "Evaluation of Methodology for Estimating the Cost of Air Force On-the-Job Training," Air Force Human Resource Laboratory, November 1974.

35. Ibid., Samers et al., p.16.

36. Note that the sample sizes involved here appear substantially lower than in most of the studies reviewed to this point. The Weiher and Horowitz study surveyed some 1900 supervisors across Navy ratings in making their cost estimates. For some individual ratings their sample size was similar or fewer than those listed here. Weiher and Horowitz combined "similar" ratings however in making their cost estimates by category, thereby reducing the sample size concern.

37. Samers et al also found no difference in the performance of technical training school graduates and OJT trainees, saying "neither type of training results in superior performance at the 5 level." (p.17)

38. Ibid., p.13.

39. Note that in both the Phase I study of the administrative specialist and in the earlier Dunham study of the communications center specialist, technical training school costs were shown to exceed the costs of staffing via OJT.

40. Samers' Phase II p.21 "If, for example, the Air Force sends more DDAs (direct duty assignees) to OJT but does not reduce the size of its technical training school faculty, then there will not be cost savings."
Similarly the ability to reduce costs due to shifting the trainee assignment procedure depends upon the dynamics of such a proposition -- i.e., training capacity constraints, economies and diseconomies of scale in training, etc.

41. Eisele, Charles R.; Bell, Thomas R.; and Laidlow, Charles D. "Cost Analysis of Air Force On-the-Job Training: Development and Demonstration of A Methodology," CONSAD Research Corporation for AFHRL, TR-78-88, May 1979.

42. Use of existing data systems, even if imperfect, was seen as a way of bypassing the costly and time consuming requirements of data collection imposed by previous studies. This feeling is typified by the following quote:

> "Gay has described some aspects of an approach to training cost assessment that attempts to capture the value of the human capital invested in OJT programs. Such a theoretical approach has provided guidance in establishing cost categories but remains too cumbersome to be used in a working cost methodology" (Eisele et al, p. 8).

43. ibid., Eisele, pp.75-76.

44. ibid., Eisele, p.76, Specific duties from the specialty job description were estimated to require 61.9 percent of trainee time; 38.1 percent of trainee time was estimated attributable to OJT.

45. The proposition that time not spent on job description duties must have been spent on OJT is difficult to accept.

46. ibid., Eisele, p.156.

47. Calculating costs per trainee by multiplying costs per trainee month by the average number of months to proficiency yields much higher cost estimates in the Eisele study than in previous studies. This may be due to the rather questionable assumption Eisele appears to make that time not spent in job description duties must have been spent in OJT. Note however that the Eisele estimates are "in the same ballpark" as Samers' Phase II study utilizing the conditional models.

48. ibid., Gay. p.9-10.

49. While the military views individuals as being on duty 24 hours a day, it seemed appropriate to try to measure actual hours actively worked (on average) to get a more realistic measure of supervisor costs.

50. Theory requires valuation of individual time according to the contribution the individual makes to production; that is, the individual's marginal value product. However, the military pay structure does not include a system of occupation wage differentials (the one major exception to this statement is the system of selective reenlistment bonuses that do vary by occupation). Rather wage differentials are predominantly based on differences in length of service. Consequently, use of the military pay package to proxy individual contributions to defense output implies that a cook, a tank crewman, a computer operator, and a satellite equipment repairer all contribute equally to the production of defense. Problems with this assumption should be self evident. As one example, if the size of the force is fixed (i.e. the decision being studied is whether to increase training activities without changing force size), wage costs are sunk costs. In that situation, wages are a precise measure of opportunity cost only if they happen to measure value of activities foregone.

51. In both cases we used figures for Regular Military Compensation (RMC) as recorded in the table entitled "Cash and In Kind Pay Grade Averages" from the Department of Defense publication Selected Military Compensation Tables: October 1981 Pay Rates (OASD (MRA and L) MP and FM – Directorate of Compensation). For purposes here we used the figure for an E-3 and E-5 with less than two years of service and translated the annual amount into a monthly figure by dividing by 12. One may question the use of the "less than two years" category for E-5's, since an E-5 with less than two years of experience is probably extremely rare. (The mean time for promotion to E-5 in this MOS in fiscal 1981 was 3.48 years). However, since we are using this figure to value output during training, it may be quite sensible

to value this output at a rate slightly less than the average E-5 receives. In any case, there is nothing sacred about the choice of E-3 and E-5 with less than 2 years of service. If for some some reason a different proxy is desired, all estimates can easily be recalculated.

52. In other words, proficiency was assumed to increase linearly between points on the learning curve.

53. Figures again taken from Department of Defense source described in footnote 51. We arbitrarily selected figure for lowest years of service for use in our calculations.

54. Hindsight has confirmed the wisdom of this decision. It is our feeling that many of our most important insights would have gone undetected if the questionnaire had been otherwise administered.

55. Personnel at Camp Roberts have been assigned to handle the overdue AN/MSQ 114 as soon as it arrives.

56. Estimates using a linear approximation of the learning curve in computing trainee time costs.

57. See the earlier discussion of the study by Samers for additional description of this point.

58. Apparently the Navy uses a system like this for some skilled electronics occupations.

59. Our understanding is that recent changes in methods of training and assignment may mitigate this problem.

60. Another important advantage of personnally administering the questionnaire is the volume of additional useful information (not embodied in the questionnaire) one is able to pick up. This is illustrated by our discussion in the preceding section, which is based almost entirely on interviewee responses not directly related to specific questions on our questionnaire.

Appendix I

A Comparison of OJT Cost Estimates
from Previous Studies

While sharing a common theoretical point of departure, studies estimating OJT costs in military settings have employed different cost estimation equations and techniques. It is, therefore, worthwhile to provide a more detailed analysis and comparison of these cost estimates. Since trainee and supervisor costs emerged as the major components of OJT costs in each study, our comparison of OJT cost estimates will focus on these two cost elements. The studies will be reviewed chronologically.

Weiher and Horowitz

Weiher and Horowitz (1971) looked at a number of Navy occupational ratings and sought to cost two methods by which these ratings are staffed: 1) by direct fleet assignment and skill acquisition entirely on the job; and 2) by assignment to formal schools (A schools) for training in the rating prior to fleet assignment and OJT. Their estimate of trainee time costs during OJT was the difference between trainee's salary and benefits in a particular month of OJT and the value of the trainee's production during the same month, summed over the number of months of training.

$$\text{Trainee Time Costs During OJT} = \sum_{t=1}^{n} (S_t - P_t)$$

where S_t = salary and benefits in month t of OJT,
$\quad\quad P_t$ = value of trainee OJT productivity in month t,
$\quad\quad n$ = the number of months of OJT required for the trainee to become proficient (i.e., prepared to take the 3rd class exam).

The value of trainee productivity during OJT (P_t) was approximated by

$$P_t = \alpha_t \beta_t S_{4t}$$

where P_t = value of trainee production during month t of OJT
$\quad\quad \alpha_t$ = the proficiency of a trainee relative to individual ready to take the 3rd class exam

$\int_t$ = the proficiency of an individual ready to take the 3rd class exam relative to a new E-4

S_{4t} = the pay and benefit rate of an E4[1]

The value of α for each OJT month was extracted from learning curve diagrams supervisors were asked to draw. Similarly, supervisors recorded the proficiency of an individual ready for the 3rd class exam relative to a new E4.[2] This value constituted the estimate for β and accounted for growth in the productivity of a new E4 relative to an individual ready to take the exam (as a result of the 3rd class exam being given only twice a year and the consequent passage of additional months of informal OJT). The term $\alpha_t \beta_t$ S4t consequently represents the value of the OJT trainee's output in terms of the value of a fully trained journeyman's production over the same time period. This idea is made clear with the aid of Figure 8.
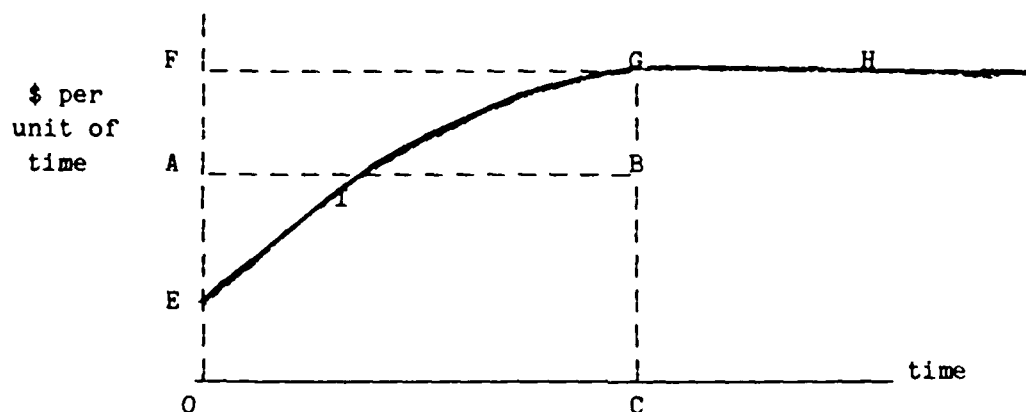

Figure 8. The "Learning Curve."

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1 See Weiher and Horowitz, page 10, and Gay, pp. 46-47, for a detailed description.

2 Weiher and Horowitz use the new E4 to approximate a fully proficient journeyman.

EIGH represents the learning curve of the OJT trainee following graduation from A school (that is, from formal classroom training), expressed in terms of the value of his/her productivity. Full proficiency (the productivity of a new E4) is reached after C time units of OJT. AO represents the trainee's wage during each of the C periods of OJT and is Weiher and Horowitz's measure of the opportunity cost of trainee time.

The diagram can be used to help visualize their estimate of trainee time OJT costs, $\sum_{c} (S_t - P_t)$. In the diagram the area ABCO is equivalent to $\sum S_t$, the total salary and benefits paid to the trainee during OJT. Area EGCO corresponds to the $\sum_{c} P_t$ term and represents the total undiscounted value of the trainee's output from entrance to the unit until full proficiency. What then is the trainee time cost of OJT? It is the area ABCO minus EGCO. Having the region EIBCO in common, the comparison of the two areas reduces to AIE minus IGB. This difference (AIE-IGB) is the undiscounted trainee OJT costs estimated for each rating in the Weiher and Horowitz study.

Respondents also were asked the percentage of time OJT supervisory personnel of various pay grades typically spend instructing OJT trainees. This figure was multiplied by the salary and benefit package of a supervisor in the various grades. Summing over the pay grades and multiplying by the months of OJT required to reach proficiency yielded an estimate of OJT supervisor costs.

$$n \sum_{k=4}^{9} a_k V_k$$

where

n = number of months of OJT required for the trainee to be prepared to take the third class exam

a_k = percent of time a supervisor of pay grade k spends instructing OJT trainees

V_k = wage rate of a seaman in pay grade k.[3]

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3 Formulation described in Gay, p. 46.

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Trainee and supervisor time were the only cost elements included in Weiher and Horowitz's OJT cost estimates. While they made cost estimates for a number of ratings, those reported here were chosen to permit comparison with subsequent studies using Air Force occupations. For the rating, Aviation Machinist Mate with prior A School training, Weiher and Horowitz recorded OJT trainee pay costs of $1529 and OJT trainee output of $1271 for a net OJT cost estimate, excluding supervisor costs, of $258. Adding supervisor costs of $4515 yielded a total OJT cost estimate of $4773 per trainee.[4]

Distinctive here is the relatively large magnitude of supervisor costs in comparison to trainee costs. Supervisor costs were even larger in the case of non A-school staffing since that training route involves additional OJT time. For non A-school trainees, in the rating mentioned above, trainee pay costs were $2760 and OJT trainee output $1882 for a non supervisory cost total of $908. Addition of $7839 of supervisor costs produced a total training cost estimate of $8747 compared to $6358 (including A-school costs) for the A-school route. The Weiher and Horowitz estimates of supervisor costs far exceed those of any subsequent study. While this may result from some funda-mental difference between Navy and Air Force OJT, we earlier mentioned possible reasons for this discrepancy stemming from the manner in which the question-naire was constructed.

Dunham

The Dunham study provided estimates of OJT costs to 3-skill level for a single Air Force Specialty Classification (AFSC), the Communications Center Operations Specialty. This specialty is similar to that of Weiher and Horowitz in that it is an Air Force Category B specialty -- a specialty staffed approximately equally of individuals having completed formal technical training and those receiving direct duty assignment and skill

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4 See Weiher and Horowitz, Table IV, line 4, item (10). Note that the difference between the table value ($6358) and the text ($4773) reflects the fact that the table estimate is total training costs and includes formal school costs of $2585. As will be discussed later, this was evidently neglected by Gay in comparing his results with those of Weiher and Horowitz (See Gay, p. 15).

upgrading through OJT alone. The Dunham study is distinctive for collecting data on OJT cost elements beyond trainee and supervisor time.

Dunham collected information on the average number of weeks of training needed to reach proficiency in 19 different categories of skills related to the Communications Center specialty. For each of these skill categories, data were collected on the average weekly hours the typical OJT trainee spent in OJT-related reading and the receiving of OJT instruction. The cost of trainee time was extracted from this information by the following formula:[5]

$$\left(\begin{array}{c} \text{Hourly Wage} \\ \text{of a Trainee} \end{array} \right) \sum_{i\,=\,1}^{19\ \text{Skills}} \left[\left(\begin{array}{c} \text{Weeks to} \\ \text{Proficiency} \\ \text{for Skill i} \end{array} \right) \left(\begin{array}{ccc} \text{Weekly Trainee} & & \text{Weekly Trainee} \\ \text{hours reading} & + & \text{hours in} \\ \text{for Skill i} & & \text{instruction or} \\ & & \text{practice of} \\ & & \text{Skill i} \end{array} \right) \right]$$

This equation does not separate trainee opportunity cost and trainee OJT production as neatly as the Weiher and Horowitz trainee time cost equation. The diagram used earlier is useful for comparing the two costing methodologies.

In adapting the diagram to the Dunham approach, the distance OC should be viewed as the total number of OJT weeks necessary for proficiency in the 19 skills surveyed. Think of the vertical axis as measuring numbers of hours, with OF representing 40 hours per week. The EIGH schedule in the diagram can then be thought of as representing hours of full production during OJT. Average weekly training hours spent in reading, in being instructed and practicing the 19 skills, when added together, constitute nonproduction or OJT hours in the Dunham scheme. For example, at time period t_o (entrance to OJT) the trainee spends OE hours of the work week in production. The difference between a full work week and the hours the trainee spends in

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5 Formula taken from Dunham, p. 14.

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production (this difference being the distance EF at time t_o) is the total hours spent in on-the-job training by the typical trainee at that particular stage of OJT. As pictured the percentage of time spent in OJT activities declines as training continues and the trainee gains proficiency. At C training hours equal zero, with full production activities consuming the individual's entire work week.

Rather than ask for the number of hours spent in OJT activities at different stages of the training period, the supervisor is asked to average over the entire period of OJT. Multiplying the supervisor's estimate of the average weekly hours of OJT related activities per trainee during training by the number of weeks required to attain proficiency in the 19 skill categories yields an estimate approximating the area EFG. This area represents the amount of time the trainee is involved in nonproduction (training) activities over the entire OJT period. Multiplication of this measure of nonproduction hours by the trainee's wage is then used by Dunham as a measure of the value of the output the individual could have produced in his next best alternative employment in the military.

A number of questions can be raised concerning this cost equation. The most important issue is whether or not this measure of trainee opportunity cost is conceptually correct.[6] The trainee's wage multiplied by an estimate of nonproduction hours due to skill acquisition activities is taken as the opportunity cost. This seems to assume that an hour of the trainee's time in full production using newly acquired skill yields the same marginal value product as an hour's production in the trainee's best alternative employment (had additional training not taken place.) But, training by definition implies a gain in production proficiency over time such that more marginal value product is produced in some production hours during and after training than in the alternative (untrained) employment. This is what area IGB in the diagram represents. This area IGB (the returns to training accruing during training) offsets some of the costs of training, area AIE (the training time in which marginal value product does not reach the marginal value product of the untrained employment opportunity). This is not accounted for in the Dunham cost equation.

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6 This discussion of appropriate measure does not address questions surrounding the use of trainee wages as the opportunity cost measure. Assume the trainee wage is the appropriate opportunity cost to the firm.

This point can alternatively be seen by realizing that the area AFGI must be a cost of training--a loss of production if the Dunham measure is to be conceptually correct. For this to be true the value of the trainee's production in the pre-training occupation or employment would have to equal the value of production in the occupation in which training was being received. If this is not the case, then AIE should be the only cost of training representing the training time in which the individual's marginal value product does not reach his/her marginal value product in the next best employment opportunity. These considerations would suggest possible upward bias in Dunham's estimate of trainee time costs.

A couple of conceptually less serious factors may possibly contribute to an overestimate of trainee time costs with use of the Dunham questionnaire. First, Dunham's definition of OJT hours included "hours per week being instructed or practicing" particular skills. In an OJT setting, practicing skills could involve production. To the extent that actual production occurs during "practice," production hours would be underestimated and pure OJT hours overestimated. Second, the questionnaire listed 19 skill categories and asked the supervisor to list "the number of weeks it takes the average trainee to reach 3-level proficiency" in each skill category. The average weeks to proficiency in the occupation was determined by summing the estimated weeks to proficiency for each of the 19 skills. If any economies of scale exist in skill acquisition (the trainee learning multiple skills in a particular week of training) and these are not properly accounted for by supervisors in calculating nonproduction hours per trainee per week, this would further bias trainee time cost estimates to the high side.

Dunham's estimate of OJT supervisor costs was made on the basis of the formula:

$$\left[\frac{\sum_{i=3}^{7} \left(\begin{array}{c} \text{Number of instructors} \\ \text{with grade i} \end{array} \right) \left(\begin{array}{c} \text{Hourly wage of} \\ \text{instructor with grade i} \end{array} \right)}{\sum_{i=3}^{7} \begin{array}{c} \text{Number of instructors} \\ \text{with grade i} \end{array}} \right] \bullet$$

$$\left[\sum_{i=1}^{19 \text{ skills}} \left(\begin{array}{c} \text{weeks to} \\ \text{proficiency} \\ \text{in skill i} \end{array} \right) \left(\begin{array}{c} \text{instructor hours} \\ \text{per week in} \\ \text{skill i} \end{array} \right) \left(\begin{array}{c} \text{instructor to} \\ \text{trainee ratio} \\ \text{for skill i} \end{array} \right) \right]$$

The second bracket computes the number of grade-specific instructor hours per trainee over the period of OJT. The first bracket values these hours according to the hourly wage of instructors of particular grades. The methodology is similar to that of Weiher and Horowitz, but has the advantage of not forcing supervisors to explicitly calculate instruction hours by grade on a per trainee basis.

Dunham's mean estimate of undiscounted OJT costs to the 3 skill level in the Communications Center Operations specialty was $1453. Trainee time accounted for $615 of this figure while instructor opportunity cost was estimated at $412. The remainder ($426) was attributed to the detailed cost elements Dunham included in his estimate, of which delays in entering training ($259) was the most sizeable.[7]

Dunham's estimate of total OJT cost in this specialty is significantly lower than the Weiher and Horowitz estimate for the Navy Aviation Machinist Mate ($4773). Even after considering the difference in occupations, the gap between the estimates remains stark. Differences in supervisor costs is the major source of the difference in the estimates. We have suggested why the WH supervisor cost figure might be an overestimate. The basic similarity of supervisor cost equations in the two studies provides an indirect test of that supposition. Dunham's estimate of trainee time costs, which we argued is biased upward, does in fact exceed that of Weiher and Horowitz. While we have suggested possible reasons for this difference, it must be evaluated in light of any differences in weeks to proficiency between the occupations studied.

Robert Gay

Robert Gay's (1974) estimation of OJT costs in the Aircraft Maintenance Specialty employed a unique methodology. While he defined OJT costs solely in terms of trainee and supervisor opportunity costs, he estimated the two components collectively rather than individually through the concept of the trainee's net contribution to unit performance. Net contribution is defined

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[7] Delayed Entry $259
Records Management $110
Remedial Training $30
Equipment and Material $8
Indirect OJT Costs $19

as the value of the trainee's output during training minus the value of output foregone because experienced personnel are involved in training rather than production.

Gay visualized the cost of an individual's on-the-job training as being "the present value of the difference between his value of marginal product (VMP) in his highest valued alternative employment and his VMP in the occupation in which he is being trained during the OJT investment period." The investment period was defined as "the time interval when VMP in the highest valued alternative occupation exceeds that in the occupation of training."[8] The following diagram and equations illustrate Gay's framework.[9]

Figure 9. Robert Gay's framework.
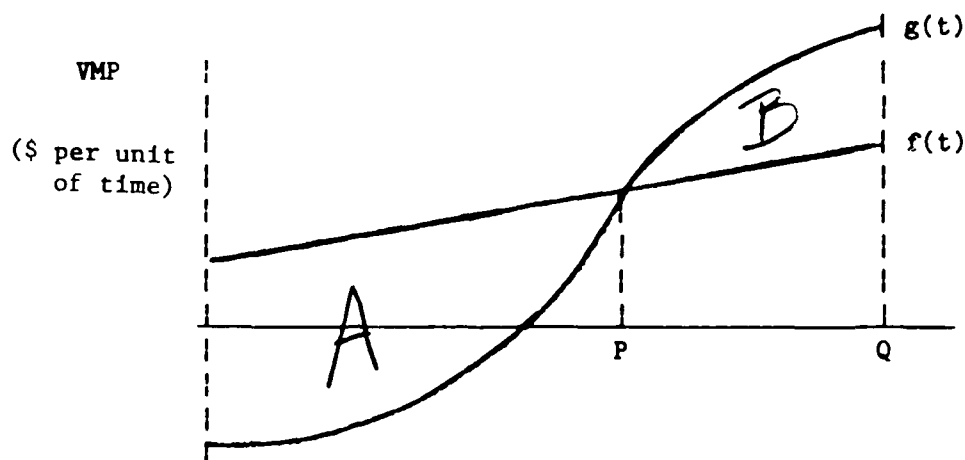
$$C = \int_{t=0}^{P} \Big[f(t) - g(t) \Big] e^{-rt} \, dt \qquad R = \int_{t=P}^{Q} \Big[g(t) - f(t) \Big] e^{-rt} \, dt$$

where
C   = costs of OJT,
R   = returns to OJT,

[8] Gay, page 8.
[9] Diagrams and equations from Gay, pages 8-9.

$f(t)$ = VMP in the alternative of training as a function of time,

$g(t)$ = VMP in the occupation of training as a function of time,

r = interest rate

P = end of the investment period

Q = end of the period of employment in the occupation

Applying these ideas to military on-the-job training Gay stated: "Consequently, the military's cost of OJT for a given individual can be viewed as the present value of positive differences between his productivity over time in his highest valued alternative military use and his actual productivity over time in the specialty where he is being trained."[10] Gay used the expected value of military pay (P_n) for the first 48 months of service as his proxy measure of alternative military use. This value was computed for each month of service ($n=1 \ldots 48$) as follows:

$$P_n = \sum_{i=1}^{m} \sum_{j=1}^{9} \alpha_{jn} A_{ij}$$

where the subscript j refers to the pay grade and i to the cost elements which included basic pay, retirement as a percentage of basic pay, quarters allowance, medical costs, separation pay, family allowance, clothing allowance, etc. A_{ij} represents the value per month of cost element i for a man in pay grade j, and α_{jn} is the probability that a man with n months of service will be in pay grade j.[11]

Gay combined his estimates of the expected value of military pay, the point of zero net contribution (t_1) and full productivity (t_2) from the survey instrument, with the assumption that "VMP increases at a constant rate until the trainee becomes a journeyman and remains constant for the

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[10] Gay, page 9.
[11] See Gay, page 10 and Appendix B, pp. 55-57.

remainder of his first enlistment." This permitted him to approximate his
theoretical construct by the following model.
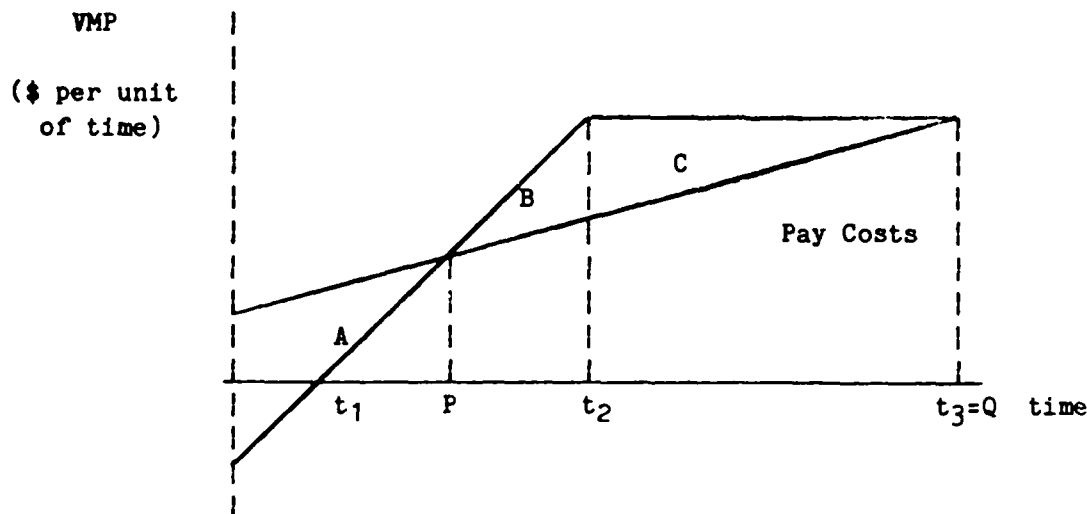
Figure 10. Robert Gay's model.

While Gay's methodology is consistent with human capital theory, a
question arises as to what Gay actually estimated as his OJT cost measure.
In terms of the diagram did he estimate area A, A-B, or A-(B+C)? If he
faithfully followed the conceptual framework as he stated it, then his
estimate of OJT costs is consistent with area A above. He also estimated
A-(B+C) to determine the Air Force's net investment in the trainee at the
end of the first enlistment. However, Gay did not estimate A-B which
appears to be what both the Weiher and Horowitz and the Dunham studies
sought to estimate. In other words, Gay's estimate of OJT costs does not
appear to account for trainee output during training. In terms of the figure
Gay appears to have estimated OJT costs associated with training from t_0 to
P rather than from t_0 to t_2 (the point when full proficiency is reached).

The average of Gay's OJT cost estimates for the typical trainee in the Aircraft Maintenance specialty was $5499.[12] Gay mentioned that this estimate was close to that of Weiher and Horowitz (which Gay said was $6358) and that the direction of the difference was correct since "the Navy AD rating is more technically demanding than the specialty studied here."[13] Gay evidently neglected to notice that the Weiher and Horowitz cost estimates were for total training (included the costs of formal training). Subtracting formal training costs ($1585) brings the relevant Weiher and Horowitz OJT figure to $4773 and confounds Gay's logic as to the direction of the difference in the two estimates. If, as suspected, Gay's estimate does not include the value of trainee production during training (Area B above), inclusion of this could restore the logic of his statement comparing the two studies.

Gay included a value for the returns to training when estimating the net first term investment in the typical trainee in the specialty (Area A - (B+C)). He estimated costs prior to OJT to average $5174 (accession cost $1414, technical school training $3161, and travel to duty station, $599). Combining these with OJT training costs yielded a total first term investment estimate of $10,674. Returns to training during the first enlistment (Areas B and C) were estimated at $4255, giving a net investment per first enlistment airman of $6419.[14]

In summary, Robert Gay's estimate of OJT costs in the Aircraft Maintenance specialty is more consistent in magnitude with those of Weiher and Horowitz than that of Dunham. However, Gay's estimate of $5499 does not include the value of trainee output during OJT which, if included, would obviously decrease the estimate. Further, Gay's methodology did not separate trainee and supervisor opportunity cost estimates and consequently does not permit comparison of cost element estimates to the estimates of previous studies.

Samers et al

The Samers study was an elaboration of Dunham's earlier efforts and an attempt to compare the Dunham approach with two alternatives. Samers termed

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12 Average of estimates in that costs are estimated for individuals in this specialty in two different settings: flight line and phase dock. $5499 figure is the average of the estimates of the two settings.
   13 Gay, p. 15.
   14 Gay, p. 17.

the Dunham methodology the "Aggregate Experience Approach" and proposed
three trainee time costing equations consistent with that approach. The
first trainee cost equation was identical to that used in the original
Dunham study.

$$\begin{pmatrix} \text{Trainee} \\ \text{hourly} \\ \text{wage} \end{pmatrix} \left[\sum_{i=1}^{n \text{ skills}} \begin{pmatrix} \text{weeks to} \\ \text{proficiency} \\ \text{in skill i} \end{pmatrix} \begin{pmatrix} \text{trainee hours} \\ \text{for skill i} \\ \text{per week} \end{pmatrix} \right]$$

The second Aggregate Experience trainee time cost equation was
conceptually identical to the first but more complex.

$$\begin{pmatrix} \text{Trainee} \\ \text{wages per} \\ \text{day} \end{pmatrix} \left[\sum_{i=1}^{n \leq 4 \text{ trainees}} \frac{\text{Date of AFSC Award} - \text{Date of Entry} - \text{weeks from proficiency to award}}{\# \text{ trainees}} \right] \frac{5}{7}$$

$$\bullet \left[\sum_{i=1}^{K \text{ training} \atop \text{week categories}} \frac{\text{non-production hours}}{40 \ (\# \text{ categories})} \right]$$

The added complexity resulted from use of administrative data on specific
trainees in estimating weeks to proficiency and the need to coordinate time
units since elements in the equation were denominated in hours, days, and
weeks. The final term yielded an estimate of the average percentage of
trainee time spent in nonproduction (training) activities per day.[15] This
value when multiplied by the bracketed term (days to proficiency) and adjusted
for weekends gave the average "effective" days of nonproduction due to OJT.
Multiplication by the trainee's daily wage was the final step in calculating
trainee OJT costs.

The third trainee cost equation associated with the Aggregate Experience
approach had a similar structure with minor exceptions. The first equation

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[15] Note that in the Samer's report, page 30, the final term of the
equation is written as $\sum_{i=1}^{N \text{ trainees}} \left(\frac{\text{non production hours}}{40 \ (\# \text{ trainees})} \right)$ where n < 6.

The question used to estimate this term did not collect data on specific
trainees. The questions that did, collected data on a maximum of 4
trainees not 6. The 6 refers to the number of week categories in which
estimates of productive and nonproductive hours were required. This
typo has been corrected in the equation in our text.

used information on time to proficiency in 19 different skills and trainee
hours per week for each skill. The second used administrative data for esti-
mating time to proficiency and an estimate of trainee hours not disaggregated
by individual skill category. In contrast, the third estimating equation
used the response to a single question as the estimate of time to proficiency.

$$
\begin{pmatrix} \text{Trainee} \\ \text{wages} \\ \text{per week} \end{pmatrix}\begin{pmatrix} \text{Time to} \\ \text{proficiency} \\ \text{in weeks} \end{pmatrix}\overset{\substack{\text{\# training} \\ \text{Week Categories}}}{\underset{i=1}{\sum}}\begin{pmatrix} \dfrac{\text{Non productive hours week i}}{40\ (\text{\# categories})} \end{pmatrix}
$$

Comparing these Aggregate Experience trainee cost estimating equations
for the Air Force Administrative Specialist occupation, Samers' mean estimates
varied from $610.24 using the first cost equation to $994.61 for the second,
with the third equation giving an intermediate estimate of $700.11 for trainee
opportunity costs. Since these estimation equations are consistent with Dunham's
original study, the estimates are subject to the same potential biases. It is
somewhat surprising that the equation using time to proficiency for nineteen
individual skills should yield the lowest cost estimate. A comparatively
"large" estimate might have been expected since more than one skill can be
learned at a time and these economies of scale may not have been properly
factored into supervisor responses. Possibly this unexpected result is due
to the manner in which the other two equations were formulated. Supervisors
were asked to split out trainee production time and OJT related reading and
instruction time, where the two had to sum to 40 hours. There may have
been a tendency to lump these other time uses in with OJT and thus artificially
increase trainee time costs in the case of the latter two estimating equations.

Samers compared the Aggregate Experience approach to two alternative
approaches, Work Sampling and Self Recording. The trainee cost equations
associated with the alternatives are listed below, the first associated with
Work Sampling and the remaining two consistent with the Self Recording approach.

$$
\begin{pmatrix} \text{Trainee Wages} \\ \text{per hour} \end{pmatrix}\left[\overset{n\ \text{trainees}}{\underset{i=1}{\sum}}\dfrac{\begin{pmatrix} \text{Trainee hours} \\ \text{receiving} \\ \text{instruction} \\ \text{last week} \end{pmatrix}\begin{pmatrix} \text{time to proficiency} \end{pmatrix}}{\text{Number of trainees}}\right]
$$

$$\left(\begin{array}{l}\text{Trainee Wages}\\\text{per hour}\end{array}\right)\left[\sum_{i=1}^{5\text{ days}}\frac{\left(\begin{array}{l}\text{Total trainee hours}\\\underline{\text{per day of week}}\end{array}\right)\left(\begin{array}{l}\text{Weeks to}\\\underline{\text{proficiency}}\end{array}\right)}{\text{number of trainees}}\right]$$

$$\left(\begin{array}{l}\text{Trainee wages}\\\text{per hour}\end{array}\right)\left(\sum_{i=1}^{5\text{ days}}\frac{\begin{array}{l}\text{Total trainee}\\\underline{\text{hours per day}}\end{array}}{\begin{array}{l}\text{number of}\\\text{trainees}\end{array}}\right)\bullet$$

$$\left[\sum_{i=1}^{n\text{ trainees}}\frac{\underline{\text{Date of AFSC}-\text{Date of Entry}}}{\text{number of trainees}}-\left(\begin{array}{l}\text{weeks between}\\\text{proficiency}\\\text{and award}\end{array}\right)(7)\right]\frac{1}{7}$$

The Work Sampling cost equation differed from the Aggregate Experience equations by using supervisor estimated trainee hours in the week preceding the survey rather than an estimate of trainee hours in an average week. Similarly, the first Self Recording equation used hours recorded daily for a week by supervisors in its computation. The second Self Recording mixed administrative data on time to proficiency with supervisor observed training hours per day during a survey week. Samers chose this second Self Recording method as his preferred methodology because of its low dependence on supervisor recall. The estimate of trainee opportunity costs of $744.60 generated by the Work Sampling equation compared closely with that of the third Aggregate Experience equation ($700.14). The estimates derived from the Self Recording approach equations ($409.78 and $570.18) were lower than those obtained *from any* other method.

Samers used a different cost equation for estimating supervisor opportunity costs in each of the three approaches. The key characteristic in the Aggregate Experience equation was, once again, the use of instruction

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hours per week per skill category.

$$\left(\sum_{i=1}^{\substack{n\ instruc-\\tors}} \frac{\substack{wages\ per\\hour\ for\\ \underline{instructor\ i}}}{n\ instructors}\right)\left[\sum_{i=1}^{\substack{n\ skills}} \binom{weeks\ to\\proficiency\\in\ skill\ i}\binom{instruc-\\tion\ hours\\per\ week\\for\ skill\ i}\binom{instruc-\\tor/trainee\\ratio\ for\\skill\ i}\right]$$

The supervisor cost equation of the Work Sampling approach replaced the
estimate of instruction hours based on all relevant past experience with an
estimate of total instruction hours spent with all trainees in the week
preceding the survey.

$$\left(\sum_{i=3}^{\substack{7\ instructor\\grades}} \frac{\substack{hourly\ wage\ of\\ \underline{instructor\ grade\ i}}}{number\ of\ instructors}\right)\left[\frac{\binom{instructor\ hours}{per\ week}\binom{time\ to}{proficiency}}{number\ of\ trainees}\right]$$

The Self Recording approach followed the same format but with instructor
hours per week being derived from supervisor recorded daily observations on
hours of training during the survey week.

$n \leq 7$

$$\sum_{i=3}^{\substack{Supervisor\\Grades}} \sum_{j=1}^{\substack{5\ days}} \frac{\binom{wages\ per\ instructor}{grade\ i\ per\ hour}\binom{instructor\ hours}{grade\ i\ per\ day}\binom{weeks\ to}{proficiency}}{number\ of\ trainees}$$

For the Administrative specialty, estimates of supervisor time costs
varied widely between the three approaches. The Aggregate Experience approach
produced the lowest supervisor cost figure ($262.38) while the Work Sampling
estimate was approximately four times this amount ($965.58).[16] The Self
Recording approach estimate of $591.35 was the intermediate estimate.

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Total OJT costs for the Air Force Administrative specialty were estimated at $1545.49 per trainee using Samer's preferred Self Recording approach.[17] Estimates derived from the Aggregate Experience based cost equations ranged from $1212.15 to $1606.52. The Work Sampling estimate of total OJT costs deviated from these other estimates due to its relatively higher supervisor costs with an estimated value of $2107. As expected these estimates of OJT costs from the Samers study are more consistent with Dunham's estimates than with those of Gay or Weiher and Horowitz. The variation in estimates shows how much influence differences in survey methodology play in generating cost estimates.

Samer's November 1974 study applied his preferred methodology from the July study to five additional Air Force Specialty Classifications (AFSC). The estimates for these occupations were similar in magnitude to those of the original Dunham study. The OJT cost estimates for these occupations are listed in Table III along with the estimates from the other studies surveyed.

Samers' estimates of trainee opportunity costs exceeded those of Weiher and Horowitz (WH) due to apparent conceptual problems in the original Dunham study. Samers' supervisor cost estimates were substantially less than the WH study possibly because of upward bias due to the phrasing of the WH survey instrument. As a result of the large difference in estimates of supervisor cost between the studies and the comparatively small difference in trainee cost estimates, the Dunham and Samers studies produced total OJT cost estimates averaging between one-third and one-half those of the Weiher and Horowitz study. Estimates of OJT costs by Robert Gay were similar in magnitude to those of WH, but his estimates were made without accounting for trainee output during OJT.

The second Samers study added one important model to those described above, the so-called "conditional" model. The conditional trainee cost model was designed to estimate trainee costs when supervisors indicated that trainees did not contribute to productivity.[18] Obviously trainee OJT

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[16] In contrast, the Work Sampling approach produced the lowest cost figure among trainee opportunity cost estimates.

[17] These OJT estimates include trainee and supervisor opportunity costs, records management time, delayed entry time, remedial training time, and equipment and materials.

Table 111

A Comparison of Military OJT Cost Estimates

Study	Occupation	OJT Trainee Pay Costs	OJT Trainee Output	Net Trainee Time Costs	Total NonSupervisor OJT Costs	Supervisor Costs	Total OJT Costs per Trainee
Weiher and Horowitz 1971	Aviation Machinist Mate (Navy - Prior A School)	$1529	$1271	$258	$258	$4515	$4773
	Aviation Fire Control (Navy - prior A School)	1142	1032	110	110	4206	4316
	Aviation Structural Mechanic (Navy - prior A School)	1684	1287	397	397	5476	5873
Dunham 1972	Communications Center Operations Specialty	--	--	615	1141	412	1453
Gay 1974	Aircraft Maintenance Specialty (Air Force)	--	--	--	--	--	5499
Samers July 1974	Administrative Specialist (Air Force) Method						
	Aggregate Experience 1	--	--	610	960	} 262	1212
	Aggregate Experience 2	--	--	995	1345		1607
	Aggregate Experience 3	--	--	700	950		1312
	Work Sampling	--	--	745	1141	966	2107
	Self Recording 1	--	--	410	793	} 591	1384
	Self Recording 2	--	--	570	954		1545

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Table III continued

A Comparison of Military OJT Cost Estimates

Study	Occupation	OJT Trainee Pay Costs	OJT Trainee Output	Net Trainee Time Costs	Total NonSupervisor OJT Costs	Supervisor Costs	Total OJT Costs per Trainee	
							A	B
Samers Nov 1974 Air Force	Pavement Maintenance Spec			$664		$773	$1687	$2411
	Fire Protection Specialist			870		1257	2550	1791
	Cook			706		996	2159	2165
	Fuel Specialist			451		534	1373	1382
	Material Facilities Spec			748		997	2238	2264
Samers Conditional (see text) model	Pavement			1010		41		1299
	Fire Protection			1615		384		2346
	Cook			1461		85		1941
	Fuel Specialist			663		68		1044
	Material Facilities			1406		111		1749

A = Obtained by summing the average results of 5 cost elements.

B = Obtained by averaging the sums of 5 cost elements for each survey.

costs using this model should be higher than in models where trainees contribute to output.[19] Similarly, the conditional supervisor cost model was used where supervisors indicated that the number of senior personnel in the unit could not be decreased if training responsibilities were eliminated, without a diminuation in unit productivity. Supervisor OJT cost estimates would then be lower in this situation than in the "normal" case (i.e., all supervisor costs in such a world would be production costs rather than training costs).[20]

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[18] The cost equation for trainee time consistent with this model was

$$\left(\begin{array}{c} \text{Trainee Hourly} \\ \text{Wage} \end{array} \right) \left(40 \text{ hours} \right) \left(\begin{array}{c} \text{Weeks to} \\ \text{Proficiency} \end{array} \right)$$

The 40 hour figure reflects the assumption that all trainee time is a relevant training cost--that no real production is taking place. In this model, then OJT is assumed to be similar to formal classroom training.

[19] Trainee costs in the conditional model minus trainee costs in the more common model should loosely approximate the value of trainee output during OJT.

[20] Samers also produced estimates for remedial training costs, records management, etc., under the conditional model. In each category (except trainee costs) costs under the conditional model are less than in the "normal" model.

Appendix II

The Questionnaire

MOS 26Y
Satellite Communications Ground Station Equipment Repairer

This questionnaire is part of research into the costs and benefits of on-the-job training in the U.S. Army. Your response is important to the completion of this project. No individual respondent's information will be made known to anyone in the Army.

The questionnaire should take less than one hour of your time. If you do not understand a question, please ask for an explanation. Feel free to write explanatory comments wherever and whenever you wish.

- -

Name: _____

Location (Fort): _____

Division: _____   Branch: _____

Grade   E- _____

               O- _____

               GS- _____

Duty MOS: _____

Years in Army: _____

Years in Duty MOS: _____

Years as supervisor in MOS 26Y: _____

Years as supervisor in related electronics maintenance MOS: _____

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1. For each of the following categories, what is the typical number of personnel in your unit?

    A. trainees (E-1 to E-4) _____

    B. E-5s or above who transferred from other MOSs and who have less than six months experience in MOS 26Y _____

    C. nonsupervisory specialists (E-5 or above not included in category B above and not serving in supervisory roles) _____

    D. NCOs in supervisory capacities (not including those in category B above) _____

    E. warrant officers (serving in supervisory capacities) _____

    F. civilians (technical representatives involved in training capacities) _____

2. For each of the following categories, what is the typical number of personnel working at the work site at any moment (that is, what is the average shift size)?

    A. trainees (E-1 to E-4) _____

    B. E-5s or above who transferred from other MOSs and who have less than six months experience in MOS 26Y _____

    C. nonsupervisory specialists (E-5 or above not included in category B above and not serving in supervisory roles) _____

    D. NCOs in supervisory capacities (not including those in category B above) _____

    E. warrant officers (serving in supervisory capacities) _____

    F. civilians (technical representatives involved in training capacities) _____

3. Of the individuals in Categories A and B above entering the unit during your term of service here, what percentage arrived directly from each of the following sources?

    Technical School (AIT) _____ %

    Technical School (other) _____ %

    Other Installations _____ %

4. On average, when an individual in Category A or B above arrives
    in your unit from the above sources how proficient is he/she
    in comparison to a fully trained, proficient specialist in your
    MOS? A fully trained, proficient specialist is someone at Skill
    Level 2 you can send to repair any malfunction: who can gather
    all necessary materials, repair the malfunction, and document
    it without direct supervision.

                               Technical School (AIT) _____% as proficient

                               Technical School (other) _____% as proficient

                               Other Installations _____% as proficient

5. Based on your experience as a supervisor in MOS 26Y, consider all
    of the trainees you have supervised who have arrived in your unit
    from AIT.

        A. Some trainees in any MOS never reach the point of full
            proficiency as defined above. In your opinion, what
            percentage of trainees in MOS 26Y arriving in the unit
            from AIT will never reach full proficiency?

                                                    _____%

        B. Of the group who do eventually reach proficiency:

            i.   From the day of arrival in your unit from
                 AIT, how many months until the average
                 trainee in this group becomes a fully
                 trained, proficient specialist in MOS 26Y?

                                              _____ months

            ii. Some individuals learn more quickly than others.
                 Think of the top 20% fo the trainees arriving
                 directly from AIT. From arrival in the unit,
                 how many months until a trainee of this calibre
                 becomes a fully trained, proficient specialist
                 in MOS 26Y?

                                              _____ months

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6. In comparison to the fully trained, proficient specialist described in question 4, how proficient is the average nontrainee (E-5 and higher) at your work site?

_____% as proficient

7. If your unit suddenly found itself without trainees (E1-E4) but with the same number of supervisory personnel (E5s and above), could your unit continue to perform its mission without significantly reducing effectiveness?

_____ yes or no

8. Holding the number of supervisory personnel in your unit at its present level, how many additional trainees could your unit train under present circumstances without reducing effectiveness of operations of the unit?

_____

9. If your unit were to stop providing on-the-job training (with E1-E4s still present in the unit) would you be able to reduce the number of E5 through E8s in your unit without significantly reducing your output and effectiveness?

_____ yes or no

If yes, by how many?   _____

10. Based on your supervisory experience in this MOS, please complete the following table. Column 1 lists months in the unit (that is, months following AIT completion and assignment to a 1st duty). Please record for each time period how proficient the typical trainee is relative to a fully trained specialist.

For example, if after 3 months in the unit the trainee is typically able to complete without assistance one half the job tasks of a fully proficient specialist, record 50% next to month 3. If full proficiency is reached during the 6th month, all months thereafter would be 100%.

Months in Unit	% Proficiency
1	_____
3	_____
6	_____
12	_____
18	_____

11. Trainees spend a portion of their time acquiring and practicing new skills and a portion of their time using skills that they have already mastered. For each time period below please list the percentage of time the average trainee spends acquiring and practicing newly acquired skills.

Months in Unit	% of Time Spent Acquiring and Practicing New (unmastered) Skills
1	_____
3	_____
6	_____
12	_____
18	_____

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12. a. During an average week in your unit, how many people of each
        grade are typically in contact with the trainees in an OJT
        instructionary or supervisory role?

                                                E-5s   _____

                                                E-6s   _____

                                                E-7s   _____

                                    Warrant Officers   _____

                                            Civilians   _____

    b. What percentage of his/her work hours does an individual of
        each supervisory grade (in this MOS) typically spend in OJT
        instruction, supervision, and training-related record keeping
        during an average work week?

                                                E-5s   _____ percent

                                                E-6s   _____ percent

                                                E-7s   _____ percent

                                    Warrant Officers   _____ percent

                                            Civilians   _____ percent

    c. On average, how many hours does a supervisor (E5-7)
        in this MOS work during a typical week?

                                                            _____ hours

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To this point we have spoken in general terms about your MOS. Now, let's get more specific. Listed below are representative Soldier Manual tasks for you MOS:

#1. Ability to Use Standard Test Equipment, i.e., frequency meters, oscilloscopes.
#2. Ability to Use Manual Spectrum Analyzers.
#3. Ability to Repair a Frequency Up Convertor, CV3084.
#4. Ability to Perform a Frequency Convertor Noise Measurement.
#5. Ability to Repair Digital Data Modems MD-1002/G or MD-921/G.
#6. Ability to Perform Daily Maintenance (i.e. take meter readings, test fault lamps).

13. Immediately upon entering your unit from AIT (i.e. with no on-the-job training) which of these tasks can the typical trainee perform without direct supervision?

Task #s _____

14. Upon arrival from AIT how proficient is the typical trainee in these tasks (taken together) in comparison to a fully proficient specialist?

_____ % as proficient

15. How long after completion of AIT is the typical trainee capable of performing all of these tasks in a fully productive way?

_____ months

16. Given that it takes this long to become fully productive in all the tasks, is the typical trainee fully competent in any of them after half the time?

_____ yes or no

If yes, which?   Task #s _____

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17. Here is a list of terminals often found on the worksite of your particular MOS. Please check those items that are in fact found at your specific work location.

_____	AN/FSC-78	_____	AN/GSC-49
_____	AN/MSC-46	_____	AN/TSC-85
_____	AN/TSC-86	_____	AN/TSC-93
_____	AN/TSC-54	_____	AN/MSQ-118
_____	AN/GSC-39	_____	AN/MSQ-114
		_____	other (specify)

18. What percentage of a trainee's day is actually spent performing maintenance and doing repairs?

_____ percent

19. What are the 2 major reasons that this percentage is not higher?

1. _____

2. _____

Thank you for your assistance.

Page 96 in this report is intentionally
left blank.
Per Mr. Douglas Edwards, ARIBSS

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APPENDIX III

Possible Questionnaire Modifications

A number of difficulties with the questionnaire were discovered in
the course of our interviews and analysis. This Appendix discusses the
nature of the difficulties with specific questions. The discussion
follows the order of the questions in the questionnaire itself.

On page 1 of the questionnaire, the only major difficulty involved
the notion of "branch" and "unit." The information we wished to solicit
involved the actual "work site" within the satellite tracking facility.
At Fort Detrick, for example, there were three distinct work sites with
quite different duties: the Earth Terminal, the DSCSOC, and the 114 terminal.
The Earth Terminal actually tracked the satellite, the DSCSOC determined
how the spectrum on the satellite was to be allocated (and how this
allocation was to be adjusted as user demands changed) and the 114
controlled tactical communications (through the satellite) among actual
Army units. Our unit-branch distinction did not always succeed in eliciting
this worksite information. If the relevant work-site distinctions are
known beforehand, an explicit question can be designed. Knowledge of
the range of work sites can be obtained by pre-interview discussions
with the commanding officer.

Two more minor possible modifications of page 1 are worth considering.
First, the last five lines are not well-designed to solicit information
about the backgrounds of civilian repair personnel. Second, we sometimes
found ourselves wishing that we had appended to the last line the question
"name of related electronics maintenance MOS." This was largely to
satisfy our own curiosity; it was not clear that this information could
be used in the analysis.

On page 2, Questions 1 and 2 raise the issue of what information
should be gotten directly from company records. The typical training
supervisor is unlikely to know the precise answer to Question 1, which
involves the size of the entire staff. Thus, this information should be
obtained from company records (or from the officer in charge). It is useful
to ask Question 2 of each supervisor, but it should be reworded to make

it clear that it is the supervisor's own _typical shift_ one is asking
about. It is possible that the supervisor gets rotated from one shift
to another. This possibility needs to be allowed for. "Size of shift"
information should also be obtained from company records (from the officer
in charge) for consistency checks.

On page 3, Question 4 involves several different difficulties.
First, the definition we gave of "fully proficient" turned out to be too
stringent. We were told by a number of the most experienced supervisors
that _no one_ can repair "any malfunction." This situation exists because
some complex malfunctions are so infrequent that no one has experience
with them and because technology is constantly changing. One possibility
is to change "any malfunction" to "most" or "85%" or some other high
number. Another possibility is to change the wording to something like
the following: "A fully proficient individual is one who can handle any
problem that occurs; using technical manuals and his/her knowledge, the
individual should be able to fix most problems and at least accurately
diagnose unusual problems." Neither of these possible changes is a
completely satisfactory solution to the problem of defining "fully
proficient." A second problem with Question 4 concerns the "% as proficient
from other installations" (or from other technical school) question.
The answer will vary greatly depending on the amount of experience of
the individual. Thus, this section of the question does not yield much
useful information. A third problem concerns whether Question 4 (in
conjuction with 5B1) is really necessary. It essentially provides
information that Question 10 gives in more useful detail. Unless one is
trying for reliability checks, 4 and 5B1 may be expendable. We also had
the feeling that Question 10 was better understood by interviewees,
though this may be due to having been subjected to Question 4 first. A
problem with all these questions (4, 5B, and 10) for some interviewees
is that they had trouble thinking in percentage terms. The solution for
that difficulty is not at all obvious.

Question 5A was meant to elicit information on the presence of
individuals incapable of learning the skills involved in 26Y.
Unfortunately, it runs into the difficulty that some interviewees answered

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taking into account the fact that some trainees do not stay long enough to get proficient. Some of these trainees could learn if they stayed long enough.

On page 4, questions 7-9 are borrowed from the Samer study and are meant (in a rough way) to get at the true opportunity cost of supervisor and trainee time. Unfortunately, responses are probably colored by the perceived self-interest of the supervisors being interviewed. It is not obvious how to change the questions to ameliorate this problem.

On page 5, the "months in unit" scale for question 10 needs to be expanded in length. There seemed to be a tendency to fill in 100% for the last listed category (18 mos), even though verbal discussion suggested that full proficiency took considerably longer. This problem would be remedied by expanding the "months in unit" scale to, say four years. We mentioned above the problem that some supervisors had difficulty thinking in terms of percentages. An alternative way of asking these questions is by using diagrams, a technique used in the Weiher and Horowitz study. It is unclear whether using diagrams is in fact an improvement.

Question 11 on page 5 should be eliminated. Interviewees found it extremely difficult to understand and when they finally understood it (some interviewees never did), they basically repeated the information in 10.

On page 6, Question 12a needs to be reworded to make it unambiguously clear that what is being asked is number of supervisors per shift per week, not per site per week. This makes the answer consistent with the number of trainees per shift information elicited in a corrected version of question 2. It was also suggested to us that more experienced E-4's might do some training; this implies adding an E-4 category to Questions 12a and b. This might, however, create a good deal of confusion.

On page 7, the introductory wording needs to be changed. It's too condescending-folksy. In addition, we are not sure that much additional information is gained by this battery of task-specific questions. If they are retained, we suggest two changes. First, Question 13 should be altered to read "immediately upon entering the unit from AIT and being given a brief introduction to the equipment and its location, which of these tasks...." This change is to make it explicit that some minimal

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amount of specific training is expected. Second, Task 5 should be dropped from the list (perhaps a substitute task might be listed). It turns out that some extremely proficient individuals do not feel at ease with this task.

On page 8, Question 17 should be eliminated. This information should be collected from the officer in charge. Question 18 should be changed by adding a term such as "performing operator duties" to "performing maintenance" and "doing repairs."